DISCOVERY

Monthly Notebook
Atomic Plans — Penicillin for All—Controlled Crystal Growth—Insects and Fungi

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International Control of Atomic Energy
Memorandum to U.N.O. from Nineteen Atomic Scientists

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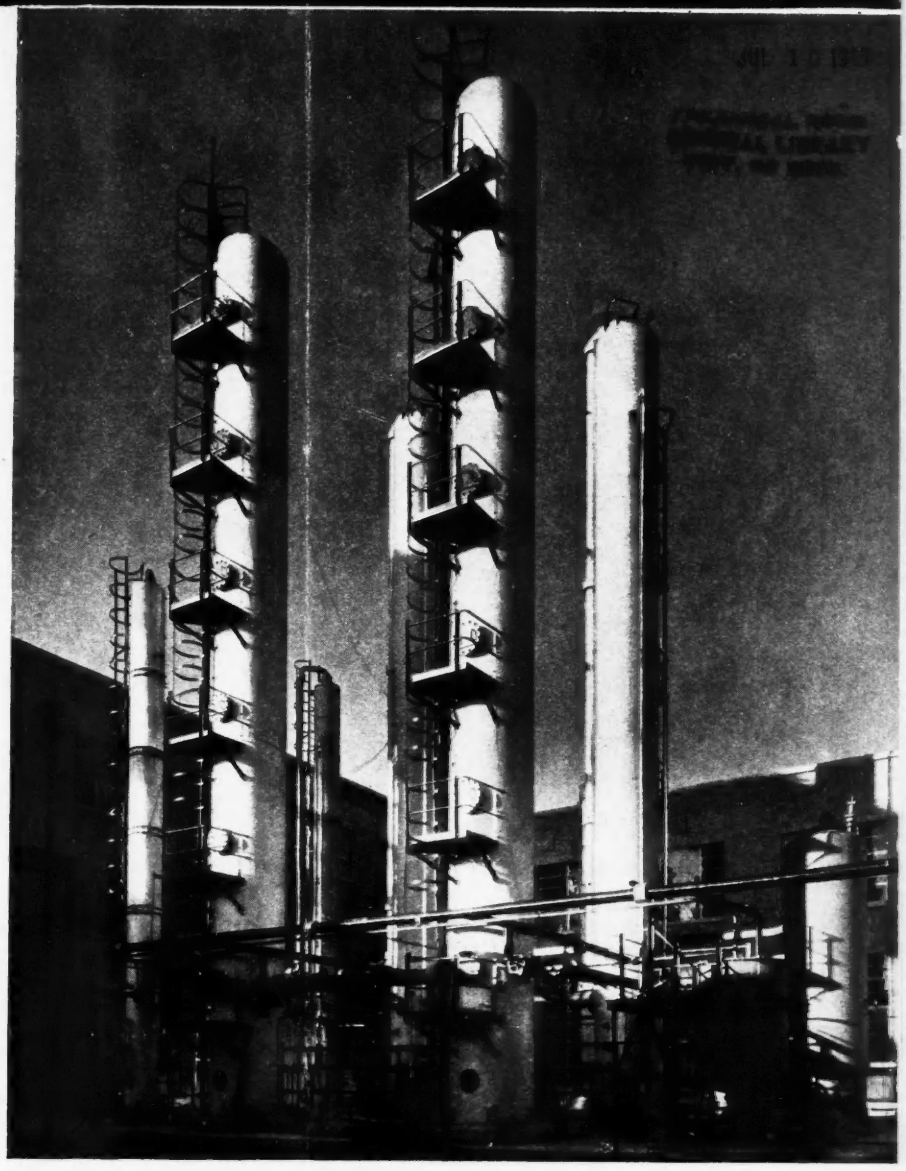

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THE MAGAZINE OF SCIENTIFIC PROGRESS

June, 1946 Vol. VII. No. 6

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The Progress of Science

Plans for the Atomic Age

WHEN the first atom bomb was dropped, those not in the inner ring thought there would be great scientific problems to be solved before atomic energy could have peaceful applications. It soon became clear that research to that end had progressed further than the first official statements had indicated. The release of more information brought a realisation that the unsolved problems were largely technological. But more important than either scientific or technological problems are the political problems arising from the atomic bomb; for there will be little effective research on peaceful atomic energy until governments can get away from preoccupation with security, and in particular until the present walls of secrecy are broken down. Two recently published official documents illustrate this effectively, but in very different ways.

The first is *A Report on the International Control of Atomic Energy*, a U.S. Government publication (reprinted by the British Stationery Office), a report by a committee under the chairmanship of D. E. Lilienthal of the Tennessee Valley Authority. The Lilienthal Report is the most encouraging one on the subject that has yet appeared. It is encouraging because of the actual recommendations contained in it, but even more because of the positive and progressive attitude that permeates it. The emphasis is on making atomic energy available to the world, and the problem of the atomic bomb takes its rightful place as the main difficulty standing in the way of that desirable object.

The Lilienthal Report introduces the world to an important new concept—that of denaturing an 'explosive' isotope (one that can be used in bombs) with another isotope that will not interfere with its use for peaceful purposes such as industrial power production. The mixture would be little or no use as an atomic explosive. For instance, the plutonium used in the Nagasaki bomb has apparently at least one isotope; the mixture of plutonium isotopes could only be separated on the basis of their very slight physical differences, and such a separation could only be effected in a large plant which it would be difficult to keep secret. The scale of the plant necessary would also mean that it would take a long time to get it into substantial production. The Lilienthal Committee does not contend that a system of control based solely on denaturing could provide adequate safeguard, but it does suggest that denaturing can help to make control easier.

The plan it advances is based on three main axioms. First, for technical and other reasons, no merely negative type of control, no 'police' control based mainly on inspection, will work. Second, legal and illegal activities must be distinguished in terms of the actual nature of the activity, and not in terms of purposes. Third, the international controlling body, called in the report the Atomic Development Authority, must be actively engaged in research, development and production.

The committee is convinced that all activities concerned with atomic energy can be classed as either 'safe' or 'dangerous'—the latter meaning that any persons permitted to undertake them might be in a position to evade any control and make illicit atomic bombs. They do not regard the division between the classes as a permanently fixed one, but they believe that a dividing line can be drawn at any given time, and one duty of the Atomic Development Authority would be to redraw it from time to time.

At present 'dangerous' activities would include the mining of uranium and possibly thorium and the production of uranium 235 and plutonium. At the present time control of these processes would automatically give control of the production of atomic weapons.

'Safe' activities include the use of small piles for producing radioactive materials or for research, and the operation of power piles using only denatured plutonium. As power is produced in the process of making the plutonium, this means that the actual production of atomic power would be divided half-and-half between safe and dangerous. Irrespective of intentions, dangerous activities would be forbidden to all except the Atomic Development Authority.

The uranium-235 and plutonium plants of the Atomic Development Authority would be established so as to preserve the strategic balance between nations. This is an important recommendation of the Lilienthal Committee, which visualises what would happen if a nation planning

atomic aggression seized one of the Authority's factories. Such an act would give the aggressor only an illusory tactical advantage, for it would take a long time—a year or two—before significant amounts of atomic explosive could be extracted and that would give the other powers time to take appropriate steps. A country bent on aggression would thus be denied the advantage of strategic surprise.

But safe activities would be permissible for national states or even private corporations, subject to certain licensing conditions and to inspection by the Authority. With this clear definition of illegality in terms of specific activities, there would be no difficulty in arranging inspection methods which would ensure the detection of any attempted evasion before it got so far as to be dangerous.

The fact that the line between safe and dangerous will shift from time to time means that the Authority must be in the forefront of research; it must be the first to know of any scientific developments that would change the balance. The Lilienthal committee says very rightly that the first-class men necessary to maintain this position would not work for an organisation whose functions were the purely negative ones of policing. But the right men can be attracted when police functions are regarded as one task of an international Authority which is also, and primarily, charged with far more positive responsibilities.

Thus the Atomic Development Authority, as well as certain licensing and inspecting duties, would have a series of very constructive functions to perform: surveying, control and working of uranium and thorium, the operation of isotope separation plants and plutonium-producing piles, half of the production of atomic energy, and above all very great obligations in research and development.

Of course, it is easy to criticise the plan. There are possible loopholes by which it might conceivably fail. There is the very important point that if war without atomic weapons broke out, it would quite quickly become war with atomic weapons. The only ultimate safeguard is to abolish the causes of war. But in answer to that it must be emphasised that to wait for perfection in these matters is suicidal—perfection will never come, and meanwhile the suspicions and jealousies arising from atomic monopoly will make war certain. Thus an imperfect plan that will fairly quickly and moderately safely abolish the monopoly is far more valuable than any Utopian perfection in the distant future.

It is on the question of speed of execution that the Report is most open to question. The problem of transition to international control is no easy one, especially in view of the attitude that seems to dominate American thought on the matter, the attitude that during the transition America's present advantageous position must not be threatened. The committee apparently regarded itself as obliged to sketch a step-by-step transition, in which the American monopoly of information and the American physical advantages in the possession of plant, stocks, skilled workers, and so on, will be passed over to the Authority in easy stages as the work of that body takes concrete form. As proposed, the transition would be slow. The phrase "some years hence" occurs several times and the context creates the impression that it means five or ten years rather than this year or next.

Now suspicion and 'jitters' caused by the continued atomic monopoly might very well be an important factor tending to cause future wars. Further, some years hence atomic bombs will be commonplaces and international agreement for control correspondingly difficult. And finally the peaceful applications of atomic energy are unlikely to make much progress until the bomb problem has been solved. For these and other reasons, it is very difficult to feel satisfied about the time-scale of these transitional proposals.

But even when one has criticised the timing of transition, the fact remains that this is an extremely welcome report, because it partly gets away from the short-term 'security' considerations that have dominated so much previous discussion, and because it sees the problem not merely in the negative, 'policing' form, but in the far more valuable positive form of assuring to humanity the greatest possible benefits from the fission of heavy nuclei.

Turning to the Atomic Energy Bill which was introduced in the House of Commons on May 1, one is struck by the contrast between it and the Lilienthal Report. Even after one has made allowances for the dry, antiseptic nature of the legal phraseology in which it is inevitably couched and for the necessary emphasis that has to be placed on restrictions and penalties for infringement of restrictions, one is struck by the negative character of the Bill. The context of the Bill, the manner of its introduction, was equally negative. The Minister of Supply presented it in a dutiful manner, but has not made clear that the Government seeks to promote the use of atomic energy for peaceful purposes with the least possible delay. The benefit that can come from the exploitation of atomic energy is the thing to emphasise *if* the Government has set its eyes on that target. The Government may be hesitant about placing all its resources behind such work at the moment; it may be doubtful whether exploitation of atomic energy for peaceful ends can be investigated in a big way before the problems thrown up by the bomb have been settled to international satisfaction. If that is the Government's dilemma, then it should say so. Reluctance to take the wrong step can be a very different thing from indecision, and the Government may be doing itself an injustice in not indicating clearly what are the motives behind its present apparently negative policy.

Some of the provisions of the Bill are welcome and obviously essential. It is necessary, for instance, that the Minister should be able to control all activities concerned with the production of atomic energy.

Most scientists are agreed that some restriction on the publication of their results in the development of atomic energy cannot be avoided. The restrictions are set out in Clause 11, which makes it an offence to disclose information about atomic energy plant without the permission of the Minister. The language of the clause is reminiscent of the Official Secrets Act, and one wonders whether a scientist guilty of an offence under the Atomic Energy Act to be can be prosecuted under both Acts. It is not made clear whether the Atomic Energy Act supersedes the Official Secrets Act so far as atomic energy is concerned.

In this connexion one notes the very wide definition of atomic energy given in Clause 18. This defines atomic energy as "the energy released in any process, including the fission process, which involves the transformation of/or

reactions between atomic nuclei and has been influenced by special arrangements of matter or by other applied means, but does not include energy released in any process of natural transmutation or radioactive decay which is not accelerated or influenced by external means." On this definition a cyclotron would appear to be a proscribed 'applied means', in which case the kind of research results which were as free as the wind before the war would now require the permission of the Minister before they could be published.

The word 'defence' is mentioned only once in the Bill, and that in a comparatively minor clause concerned with patents. But it is apparent that 'defence' in the narrowest sense dominated the drafting. Thus in the secrecy clause there is virtually no compromise between the assumed desirability of secrecy for military purposes and the desirability of maximum communication for all other purposes. The clause is supposed to contain safeguards ensuring that the communication of the results of fundamental research will not be inhibited. But these are virtually ineffective—for the very simple reason that exemption from restriction is provided only in cases where there is absolutely no chance that disclosure would have even a slight effect on military secrecy. Fundamental research will be very greatly inhibited, not merely in nuclear physics, but also in a very wide range of related subjects. Really first-class scientists are likely to move to other subjects—or perhaps other countries—in which this dead-weight of secrecy does not apply.

In these conditions scientists will not find much encouragement to work in the Government laboratories which undertake the development of atomic energy. They would be cut off from the cross-fertilisation of minds; they would lose the opportunity to gain that credit for good work which is dear to most scientists. They would be called on to spend a period of some ten years, say, under these restrictive conditions. These things they might be prepared to endure if there were any reasonable certainty that at the end of ten years they would have done a good job and presented the world with either real benefits or important advances in fundamental science. But even that they cannot be sure of. For, apart from the uncertainty that lies in any scientific project, there is the greater uncertainty as to whether their work would be to any significant extent devoted to positive developments. The whole atmosphere of ministerial pronouncements may lead them to believe that the primary emphasis will be on 'defence' and that beneficial results of atomic energy will be largely neglected. Such conditions do not attract the best brains of science.

How unattractive atomic energy research appears to scientists at the moment is reflected in a cynical joke that is going the rounds. A scientist is discussing his chances of survival if he adopts this branch of research as his life's work. He assesses them gloomily. "I reckon there is a 33⅓% chance that I shall die of leukemia, a 33⅓% chance that I shall die in an atomic bomb explosion and there is an equal chance that I shall end up in gaol."

While present policy continues, there is grave danger that Britain will not be able to find the right men to undertake the research and development.

We maintain, therefore, that from every important angle—from that of fundamental research, from that of the constructive uses of atomic energy and nuclear processes, and even from the narrow defence point of view—the negative policy which surrounds the Atomic Energy Bill must be replaced by a more positive one.

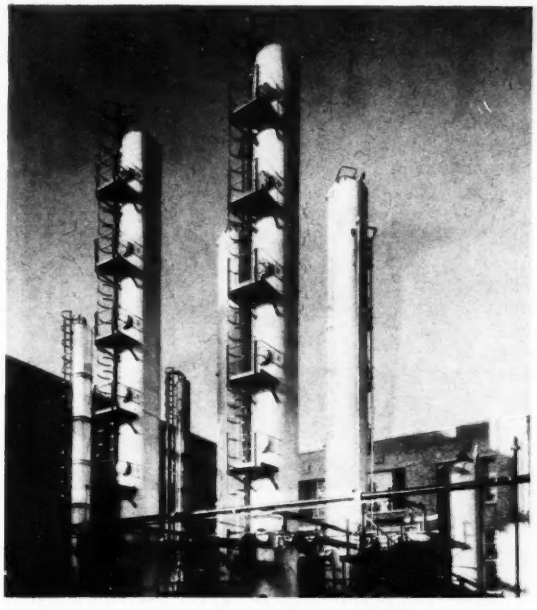


FIG. 1.—All air used at the Speke penicillin plant for fermentation purposes is scrubbed and sterilised by passing through these towers. (*Photo by Stewart Bale.*)

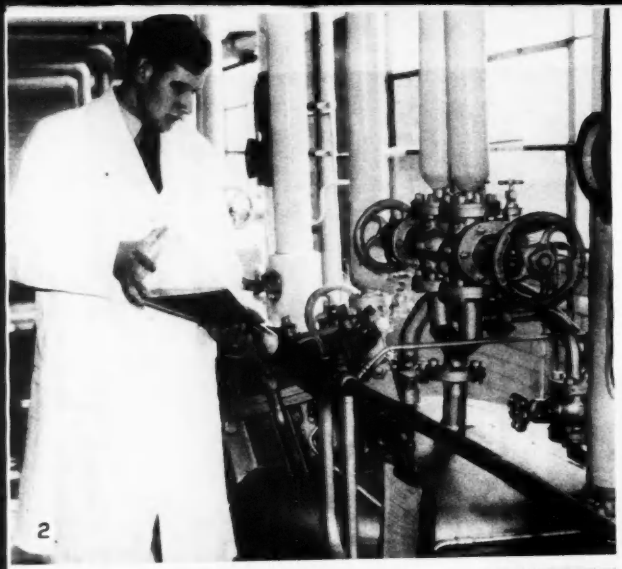
Penicillin for All

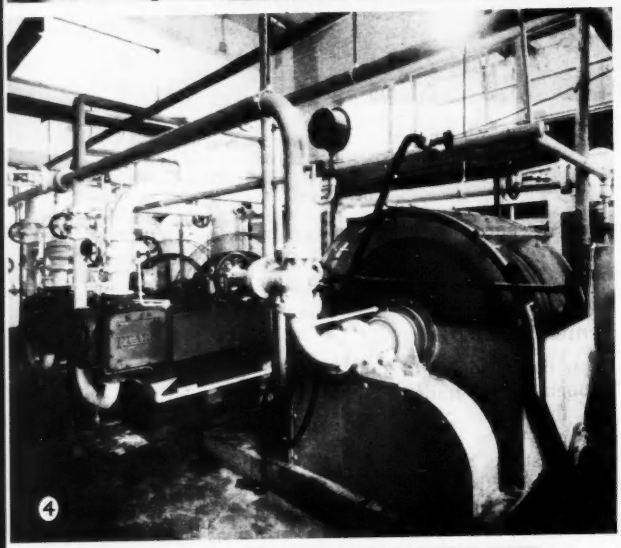
FROM the beginning of June penicillin became available through normal trade channels to hospitals, the medical and the dental professions and retail pharmacists in Britain. At the same time the free issue of penicillin by the Ministry of Supply through the hospital system ceased. But to ensure that it shall be properly used, the drug or any preparation containing it may only be supplied against the prescription of a registered medical or dental practitioner.

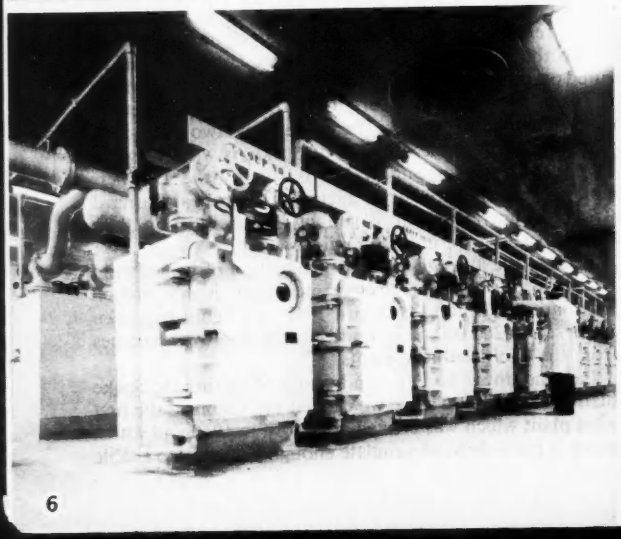
It has been possible to take this step because penicillin is now relatively plentiful. Penicillin can come into general use to the benefit of all patients whose condition can be cured or improved by its administration. This great advance is due to the adoption in Britain of the deep-tank method of producing the drug. There are now two deep-tank plants operating; one of them, at Speke, is wholly owned by the Ministry of Supply but is run by the Distillers Company as the Ministry's agents; the other, at Barnard Castle, County Durham, is run by Glaxo Ltd., on their own plant in Government premises.

In 1943 the average monthly production of penicillin in Britain was 300 mega units (a mega unit is one million International Units). By April 1946 this figure had been increased to 260,000 mega units, nearly all of which comes from the two deep-tank plants.

Last month we had an opportunity of visiting the Speke plant. In our mind's eye we carried the vision of the first pilot plant which was erected at Oxford in 1940 and which made it possible to accumulate enough penicillin to enable







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Sir Howard Florey and his co-workers to test it on animals. That was a Heath Robinson contraption, incorporating in its improvised design a household bath, a milk cooler and a number of churns. The development that has taken place in the meantime is tremendous; instead of the homely items in the Oxford plant with which the development of penicillin began there are at Speke 14 fermenters, each holding 10,000 gallons, and a refrigerating plant that would be adequate for a small skating rink. In the packaging department a conveyer belt delivers a stream of bottles at the rate of 40,000 a day—each bottle containing 100,000 units of penicillin. The weekly output of the plant is already over 30,000 mega units, and is rising.

The principles of penicillin production are much the same whether the process is carried out using surface culture of the mould or with deep fermenters, but there are differences in detail. There is one big difference in that, when the mould is grown submerged in nutrient liquor, air, essential to this aerobe, has to be pumped through in immense quantities. The sterilisation of the air in such quantities presents a major problem, and elaborate equipment is installed to scrub the air and treat it with suitable disinfectants before use. (Fig. 1.) One cannot, of course, just introduce a few mould spores into a huge fermenter and expect to get results. The spores are first 'sown' in flasks, and the mycelium that grows up from the spores is allowed to multiply, and then transferred to seed tanks of 300-400 gallons capacity. (Fig. 2.) The fermenters (Fig. 3) are then filled with sterilised broth and mould from the seed tanks. In the fermenters there is a tendency for foam to form, and this is kept under control by adding an antifoam agent, octadecanol, dissolved in nut oil. The broth contains crude lactose, Chile saltpetre and corn-steep liquor. (Cornsteep liquor is a waste product of cornflour factories; it contains proteins and lactic acid, and probably growth-promoting substances of a hormone type.)

The strain of mould used for deep fermentation is not the same as that used in surface-culture factories. It may be mentioned here that a great many new strains of mould have been produced artificially by irradiating the original types with X-rays and ultra-violet light. This treatment leads to mutation (the technique is similar to that of colchicine treatment described in DISCOVERY, December 1945) and the mould used at Speke comes from a mutant strain known as Q176, which was developed by two botanists of the University of Wisconsin.

The fermentation is allowed to proceed until the maximum concentration of penicillin in the brew is reached; this involves taking samples of the brew at hourly intervals. The optimum temperature for the mould is 75° F. and the fermenters are maintained at this temperature; heat is developed in the process of fermentation and has to be removed by circulating cold water through the jacket that is incorporated in each fermenter. Inside the fermentation tanks there is, after three or four days, a mixture approaching the consistency of the Sargasso Sea; suspended in thirty tons of broth is a mass of spongy mould mycelium, and in solution there are just three or four pounds of penicillin. The mixture is now passed through a novel kind of rotary filter, which separates the mould from the liquor. (Fig. 4.) From the latter the penicillin is removed by absorption on to activated carbon; the carbon is added to the liquor and filtered off in filter presses, the spent liquor from which is thrown away.

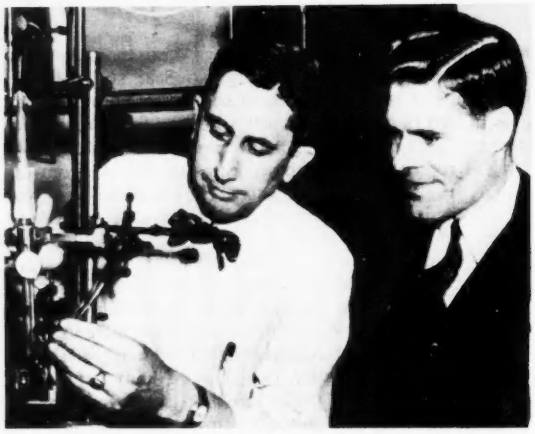
The concentration and purification of the penicillin solution that follows depends on the fact that penicillin in acid solution is more soluble in organic solvents (such as acetone and amyl acetate) than in water, whereas in alkaline solution penicillin (which is an acid) forms a salt (for instance, sodium penicillin) that is more soluble in water than in organic solvents. In a series of operations the penicillin is exchanged between one solvent and another. The final solution—in water—from this stage of extraction is now passed through a Seitz-type bacteriological filter to remove any bacteria that may happen to have got into the solution.

Penicillin is destroyed by certain bacteria, but in the extraction process just described these bacteria present no serious problem owing to the antiseptic action of the solvents involved. From now on until the penicillin is contained in sealed bottles, bacteria are a menace and the next stage has to take place in a bacteriologically sterile area of the works. This looks more like the operating theatre of a modern hospital than part of a factory, and the standards of cleanliness in the sterile area are of the same order. No one is allowed into it until he has scrubbed and donned sterilised shoes, clothing, hoods and surgical gloves. The ceilings and walls are glass-lined, and the floors are finished in impervious tarazzo which offers no breeding niche for bacteria. This section of the works is supplied with sterile air, and a slight positive pressure is maintained so that no bacteria can be carried into the sterile area when the workers enter it. To reduce the bacteria's chances still further, there are powerful ultra-violet lamps (ultra-violet light is lethal to bacteria).

Here the bottles are filled with a quantity of penicillin solution so calculated that each bottle will contain finally a single dose of 100,000 units. The penicillin solution is measured out by an automatic pipetting machine. (Fig. 5.)

Now comes the freeze-drying to remove the water from the penicillin solution in the bottles. These are packed in trays and placed in drying cabinets which reduce the temperature of the solution to 7° C. below freezing-point. The solution is frozen solid. In drying 'ovens' wherein a very high degree of vacuum can be secured, the ice sublimes off and dry penicillin powder remains. (Fig. 6.) The layman can perhaps appreciate the degree of vacuum achieved in the cabinets from the fact that the inward pull on the 'oven' doors is around 10 tons. (The technical

FIG. 2.—Inoculating a seed tank with a culture mould. In stages a stock of mould is built up until it has grown sufficiently for the contents of the seed tanks to be transferred to the 10,000-gallon fermenters, the tops of which are seen in FIG. 3. FIG. 4 shows the rotary filters which remove the mould growth from the fermented broth; when conditions are just right the spent mould comes off the filter in a continuous felt. FIG. 5.—Looking through a plate-glass window into the sterile area. Under the glass hood and stainless steel screens, bottles are filled with a measured quantity of penicillin solution by means of an automatic pipetting machine connected to the container on the left. FIG. 6—In these vacuum 'ovens' the frozen solution of penicillin is 'freeze-dried'; armour-plated doors are needed to resist the pressure of the outside atmosphere. FIG. 7—Each of these bottles contains 100,000 International Units of sodium penicillin; 300,000 bottles are stoppered, sealed and packed each week in the last section of the factory. (*Figs. 4, 5 and 6 by Stewart Bale; Figs. 2 and 7, Topical Press; Fig. 3, Sport and General.*)



Hundreds of strains of mould have been examined with the aim of increasing penicillin yields, and artificial mutations have been induced by irradiation with X-rays and ultra-violet. The mutant known as Q176 resulted from work carried out at Wisconsin University principally by these two botanists, John F. Stauffer (*left*) and Myron P. Backus.

reader will find the figure of 1-2 microns vacuum more exact.) The bottle are now stoppered, and sealed with an aluminium cover. From the time they were washed until they reach this point they go untouched by hand.

Penicillin production on the large scale is an impressive sight; the Ministry of Supply, or the firms concerned, ought to take steps to see that it is presented to the public in a film.

During the war the drug saved tens of thousands of lives and eased untold suffering. Much of the penicillin which brought that extra chance of life to British servicemen had to come to America. To the U.S.A. we have cause to be grateful for without their factories the amount of penicillin would have been pitifully inadequate. There was, however, another aspect to our reliance on America for supplies, and the suspicion grew up that perhaps the story of penicillin might repeat that of aniline dyes and optical glass. That suspicion lingered longer than necessary because of the excessive secrecy of the Ministry of Supply. Now that our deep-tank plants are operating that suspicion is dispelled. Here is one British discovery that has been developed to the point where everyone in the country can benefit from it.

Controlling Growth in Crystals

THE growth of crystals is a fascinating subject and one which has always provided a challenge to man's ingenuity, since in very few instances can crystals be grown in the laboratory to rival those found as minerals. Much progress, however, has been made recently; the growing of potassium bromide crystals of up to 25 pounds weight for use in optical instruments and the production of synthetic sapphires have already been described in DISCOVERY.

An interesting refinement of the former technique has now been developed by Dr. C. D. West of the Polaroid Corporation of America. Crystals often have different properties in different directions, particularly if the units from which they are made up are not all the same shape. Thus in the imaginary two-dimensional crystal in Fig. 9, built up of equal numbers of two different shapes of unit, the properties in the directions *A*, *B* and *C* will obviously differ owing to the different atomic arrangements. The many properties which are affected include thermal conductivity, electrical breakdown strength and refractive index. In order to make use of the differences in such properties it is usually necessary to obtain a slab of the crystal whose faces are parallel to particular crystallographic directions and since the naturally occurring faces are seldom those required a cutting operation has to be carried out, which is both costly and wasteful of material. The quartz crystals on which the Greenwich timekeeping system is based are obtained in this way. Dr. West has devised a very simple method of growing oriented slabs of sodium nitrate crystals which are of considerable importance in a number of optical instruments. Sodium nitrate crystals are melted in an oven at 320° C. A thin sheet of freshly cleaved mica is floated on to the surface of the melt and the oven is allowed to cool slowly. To avoid contamination the molten salt is contained in a dish of thin aluminium foil which is supported in a thick-walled fireclay crucible. This arrangement ensures that the mica-covered surface cools more rapidly than the rest of the melt so that crystallisation begins there. After solidification is complete, the mica sheet is stripped off (and may be used again), while the slab of sodium nitrate is found to be a single crystal in which one of the principle atomic planes is parallel with the mica surface. (Fig. 12.)

The success of this method depends on the fact that the atomic arrangement in the mica surface is very closely related to that required in the sodium nitrate. Mica is a complex mineral crystal consisting of sheets of very tightly bound aluminium, silicon and oxygen atoms held together rather weakly by potassium atoms. When a sheet of mica is freshly cleaved each surface has a network of oxygen atoms as shown in Fig. 10. Before cleavage each of the hexagonal holes was occupied by a potassium atom,

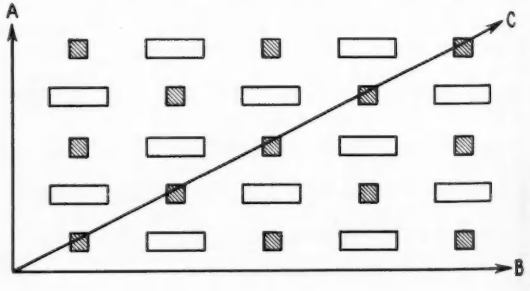
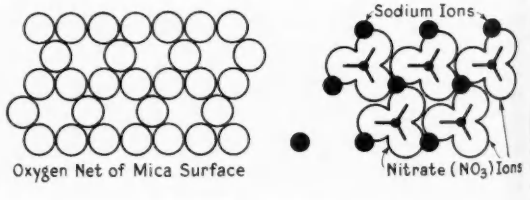


FIG. 9



(*Left*). FIG. 10 (*Right*). FIG. 11—The first layer of sodium nitrate has acquired a mica-like symmetry.

and now about half of them are left on each surface. When placed in contact with the molten sodium nitrate sodium atoms displace the remaining potassiums and occupy all the hexagons. The distance between these sodium atoms is 5·19 A.U. (Angstrom Units) which is only 0·1 A.U. different from the sodium-sodium distance in the required plane of sodium nitrate. When the melt begins to cool the nitrate ions, which consist of three coplanar oxygen atoms surrounding a single nitrogen, are accommodated above the sodium atoms in the manner shown in Fig. 11 in which the symmetry of the underlying mica network is still apparent. Once these two layers have solidified the orientation of the crystal is determined and so long as crystallisation does not start at any other part of the melt a single crystal is obtained. Actually the first layer of nitrate groups may take up two possible orientations corresponding to a rotation through 60° so that if crystallisation begins at several points on the mica surface a number of 'twin' crystals are obtained. The optical properties perpendicular to the surface are however unaffected by this.

One interesting use to which these crystals have been put is as components of a new type of gun sight in which the necessity for aligning two small objects or apertures on the target is avoided. The sight consists of a large disc, made up of sheets of polarising media on either side of a sodium nitrate crystal. This optical arrangement produces a set of concentric circles of light and darkness whose centre lies on the axis of the disc, so that sighting the gun simply involves bringing the target on to this point. (Fig. 13.)

REFERENCE

J. Optical Soc. America 1945, Volume 35, p. 26.

Insects, Fungi and Bacteria

THE story of ants that cultivate 'mushroom gardens' has been told time and time again by writers of the Fabre school, and most readers will know that there are also termites that 'organise' their food supply in the same way.

Many other instances in which insects are dependent upon fungi for their food have been collected together by

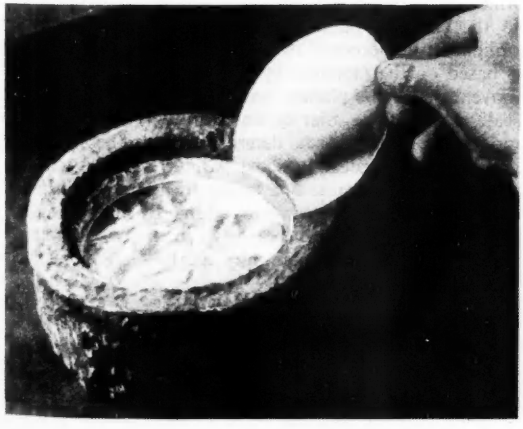


FIG. 12.—The mica sheet is stripped from the solidified slab of sodium nitrate.

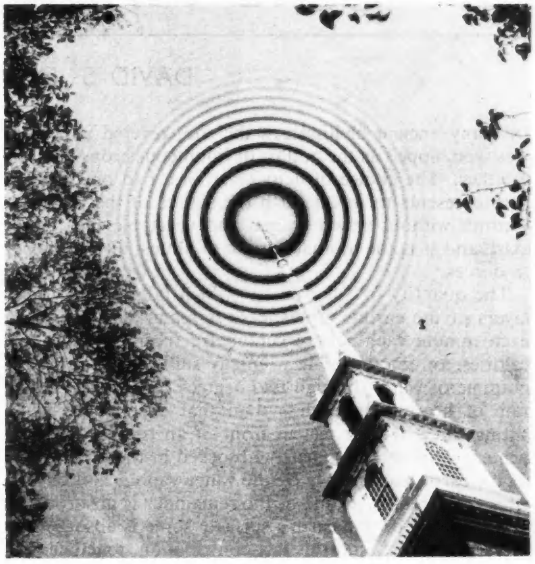


FIG. 13.—A 'target' seen through the optical ring sight.

Dr. Charles T. Brues, Professor of Entomology at Harvard University, in his new book entitled *Insect Dietary* (Harvard University Press, 1946; published in Britain by Oxford University Press, price 28*s*.).

The Diptera—the order of two-winged insects to which belong the flies, gnats, mosquitoes and midges—include many flies whose larvae feed on mushrooms and toadstools. The adult flies are common in woods in the autumn, when they may appear in swarms. Readers must have thrown away in disgust the mushroom that is riddled with maggots; these are the larvae of the mushroom gnats. Mushroom eaters are common, too, among the beetles. As Professor Brues puts it: "Many genera bear tell-tale names such as *Boletobius*, *Mycetophagus*, *Boletotherus*, *Lycoperdina*, *Mycotretus*, *Cryptophagus*, *Mycetoporus*, *Mycetina*, *Mycetaea*, etc. These names are fully as descriptive as tippler, guzzler, bacchante, milksop, boozer and the like as applied to the human species to indicate beverage addicts."

The fruit fly, *Drosophila*, with which many geneticists have worked and established their reputations (and that of the fly), has a claim to being considered 'the god or at least the father of wine making' owing the way in which unwittingly it helps to distribute wild yeasts. These yeasts are carried by insects, and in particular by *Drosophila*. At the same time as the fly deposit its eggs it also infects the fruit—grapes, for instance—with the yeasts which will later form the food of the larvae. Incidentally, moulds do not infest grapes to the extent that one might expect, and Professor Brues suggests that this is because moulds are eaten up by the fly-larvae. As the yeast grows and ferments the grape sugar a plentiful supply of food is developed for the fly larvae and the crop remains heavily infected with yeast, which is carried away in abundant quantities on the bodies of the adult fly. The heavy infection of the grape makes fermentation possible without further preparation, and to this day grapes are the fruits most generally used for

[Cont. on p. 184

The Physics of the Sun

DAVID S. EVANS, Ph.D., F.Inst.P.

In many ancient civilisations the sun, revered as a god, was worshipped as the author of bounteous crops and fair weather. The choice of deity was not a bad one, for the sun represents to us on earth the source of the light and warmth without which animal and vegetable life cannot exist, and it is the ultimate origin of almost all our power resources.

The quantity of solar energy which falls on the upper layers of the earth's atmosphere is remarkably small: in each minute each square centimetre receives about two calories, an amount of heat energy sufficient to raise one gramme of water through two degrees centigrade. It is a rate of heating rather less than that experienced when sitting three or four feet in front of an ordinary electric heater. This energy is partly absorbed in the atmosphere of the earth, particularly by the water vapour and oxygen which it contains. Some of the remainder is absorbed by vegetable life on the earth's surface: some is absorbed by the earth's crust, and this last contribution, together with a small part absorbed directly by the air, serves to warm the lower strata of our atmosphere and to maintain an equable environment. In the past, solar energy has been stored in the vegetable growth of trees which later became the coal forests, and in the bodies of minute aquatic organisms which, it is thought, later became converted into the oils which form petroleum deposits. These two crucial power sources thus represent solar energy stored in distant epochs. Energy stored more recently in the evaporation of water and its deposit in mountainous regions is available to man as hydraulic power: wind power represents solar energy stored by the heating of the earth's atmosphere. It is almost certainly true that current power assets such as hydro-electric power and wind power are not available in sufficient amounts, nor in geographically suitable regions of the earth's surface to meet the needs of the human race. The fact that coal and oil are wasting assets means that in the long run new sources of power will have to be discovered. Other sources are represented first by direct use of solar radiation, which, when concentrated by reflectors, can be used to raise steam for motive power. However, it is readily seen that, except in desert regions near the equator where the sun shines continuously, this source of power is not to be relied upon: in addition, even in such places, the size of reflector—about 250 square feet of land is needed for each horse-power generated—makes the method unattractive and scarcely practicable.

Tidal power is an exception to the general rule that all our power sources are originally derived from the sun: the utilisation of tidal power represents the extraction of energy from the rotation of the earth, using the moon and sun, the tide-raising agencies, as levers. However, the regions suited to the exploitation of tidal power are very limited as is also the amount of power which it is possible to obtain. For example, the Severn estuary represents the only serious possibility in this country, and the total power which can be generated has been estimated at 1% of the national requirements, a very important, but nevertheless small, contribution.

Even atomic energy must in essence owe something to the sun: if, as we believe, the earth was once part of the sun, the clue to the terrestrial distribution of substances from which atomic energy can already, or may eventually, be released must originally be sought in the composition and behaviour of the sun.

Even if we restrict ourselves to a discussion of terrestrial power sources our interest in the well-being and behaviour of the sun is vital, but it is now becoming clear that phenomena on earth are dependent in many other ways on solar behaviour. The maintenance of the electrified layers in the earth's atmosphere, which, by reflection of radio waves, render long distance communication possible, is a result of the absorption of solar radiation in the atmosphere: on occasion, disturbances on the sun are responsible for changes in these layers leading to interruption of radio communication, disturbances in the earth's magnetism and the appearance of aurorae.

We therefore have a clear interest in investigations of conditions on the sun, not, of course, with any hope of ever being able to control them, but rather by observation and inference to obtain understanding, and hence to make the best possible use of the conditions which are presented to us.

The determination of the distance of the earth from the sun, and the size of the latter is a matter of some complication. It is not possible to measure with any accuracy the distance of the earth from the sun directly by surveying methods based on the differences of apparent position as seen from two widely separated points on the earth's surface. This is due partly to the shortness of the available base line and partly to the difficulty of determining exactly the position of the edge of the sun. The determination is therefore carried out indirectly by the determination of the distance in miles of a body, usually Eros, which, in its movement round the sun, passes close enough to the earth to permit a determination of distance by ordinary trigonometric methods. Essentially the method is based on the fact that by observation of the apparent movements of the planets it is possible to make an exact scale model of the solar system, although the scale of the model in miles cannot be determined from these observations alone. In order to discover what the scale is it is only necessary to determine one length in the model in miles, and this is most conveniently done by measuring the distance of Eros from the earth when the two are closest together—about 15 million miles apart.

The Sun's Temperature

Once the distance of the sun in miles has been determined, its apparent size can be translated into the diameter of the sun in miles (864,000 miles). It is then also possible on the basis of the fact that at the earth's distance (93,005,000 miles) each square centimetre received 1·93

calories per minute, to calculate the total energy output of the sun. It is both a convenient example of the kind of calculation with which astrophysics, the study of the physics of the stars, is concerned, and a result useful in itself, to carry the present line of argument further and to calculate what is called the effective temperature of the sun. So far we know that the sun sends out a total of $5{\cdot}4 \times 10^{27}$ calories in each minute. The sun, with a radius of 432,000 miles (695,000 kilometres) has a total surface area of $6{\cdot}08 \times 10^{20}$ square centimetres, so that from each square centimetre of the sun there must be emitted in each minute 90,000 calories. From laboratory studies of the radiation emitted by hot bodies it is known that, generally speaking, such bodies, quite apart from their chemical composition, emit radiation of an amount dependent only on their temperature. The sun emits 1500 calories per square centimetre per second: a hot body at 5900° K* emits the same amount of radiation energy from each square centimetre per second. We therefore say that the solar surface has an effective temperature of 5900° K.

At such temperatures all solids are vaporised: chemical compounds with only a very few exceptions are split up into their constituent atoms, and many of the atoms exist, not in the form which they have at ordinary temperatures but as ions. The word *ion* is used to describe an atom which has lost one or more of its normal quota of electrons. The process of ionisation, as the formation of ions is called, can occur as the result of an increase of temperature, which is the same thing as saying that the atoms of the gas are set into more violent motion; this increased energy of motion is transferred to the electrons of the atoms in the gas and their electrons tend to become detached, leaving the parent atom as ions.

It is clear then that the sun is a globe of hot gas, and we may expect, as investigation has confirmed, that the surface temperature of 5900° K is the lowest temperature which occurs in the sun: if we were to penetrate deeper and deeper below the surface we should find regions of higher and higher temperature. It is also clear that, in spite of appearances, the sun is not burning. If one were to ask the average person about the sun he would almost certainly reply at once that the sun was on fire. However, fire is a process of chemical combination, in which atoms, for example of carbon, combine with the oxygen of the air: as we have just seen, the sun is too hot for such molecules to exist, and hence it must follow that the sun does not radiate in this way. It must generate its energy in some entirely different way which can proceed at temperatures very much higher than those which occur in flames.

Before we turn to a consideration of conditions in the sun we must first devote attention to the appearance of the sun and the changes which occur on its surface. The sun is a star, and a rather small and cool one at that, but from the astronomer's point of view it has certain features of the greatest importance. It is the only star to which we are sufficiently near for it to appear as a definite visible disc. All other stars appear to us as mere points of light, although when the new 200-inch telescope is brought into operation it will be possible to see the actual discs of some of the nearest and largest stars. This fact not only enables us to make a direct determination of the radius of the sun, a determination which is impossible or very difficult with any other star, but it also enables us to observe in detail the features of the solar surface and the changes which take place thereon.

*In ordinary life the temperature scale used is based on the freezing-point and boiling-point of water. Water is, however, a very rare substance with peculiar properties, and so in general physics a different temperature scale is used. The zero of this scale is a point which may roughly be described as the temperature at which all the heat energy has been extracted from a body. This is absolute zero or zero of the K (Kelvin) scale, and occurs at −273° centigrade. For convenience the degrees on this scale are made equal to those on the centigrade scale, so that on this scale water freezes at 273° K, and boils at 373° K. Throughout this article all temperatures will be given in degrees Kelvin.

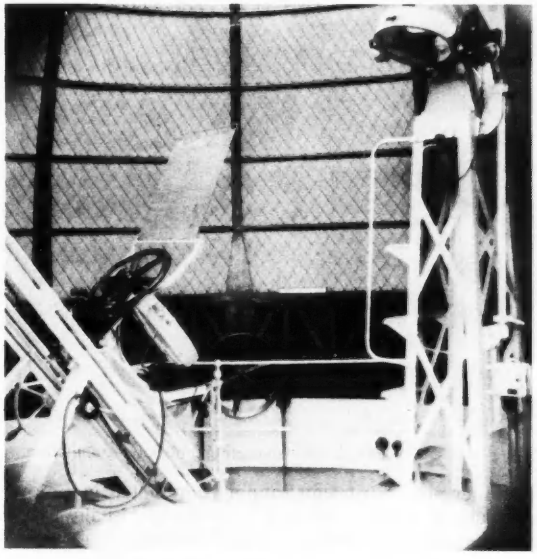


FIG. 1.—Coelostat of the Oxford solar telescope showing, on left, the primary mirror, which, rotating at half the rate of the earth, receives sunlight and reflects it to the fixed secondary mirror (top right). The latter sends the beam into the vertical telescope below (not shown). (*Courtesy, Royal Astronomical Society and Professor H. H. Plaskett.*)

Solar Telescopes

In an ordinary telescope suitable for stellar observations, the main consideration is to collect as much as possible of the far from abundant star light. The tendency in design of modern stellar telescopes is thus to make them as short as possible in comparison with their length so that, just as in an ordinary camera, the *f* - ratio is as small as possible, corresponding to opening the iris diaphragm of a camera as far as possible. Modern stellar telescopes thus tend, as in the case of the 200-inch instrument, to be of large diameter, and relatively short focal length. On the other hand, for observations of the sun, there is an abundance of light, and the main aim is to produce an image of the sun of a size sufficient to show up the smallest details on the surface. Thus solar physics tends to have its own forms of telescope, usually consisting of a telescope of moderate diameter (12-14 inches) with a focal length perhaps sixty times as great as the diameter.

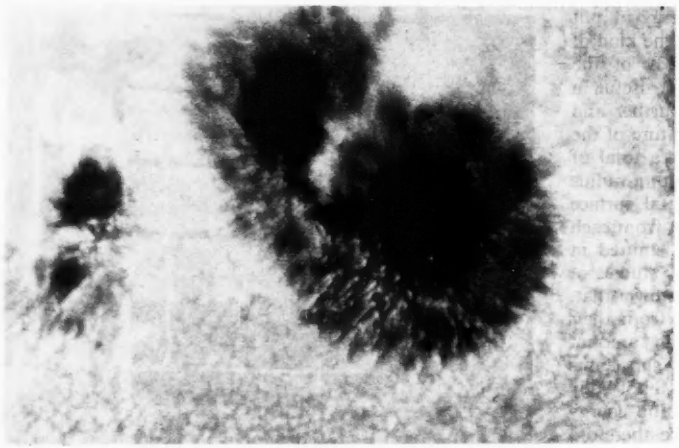
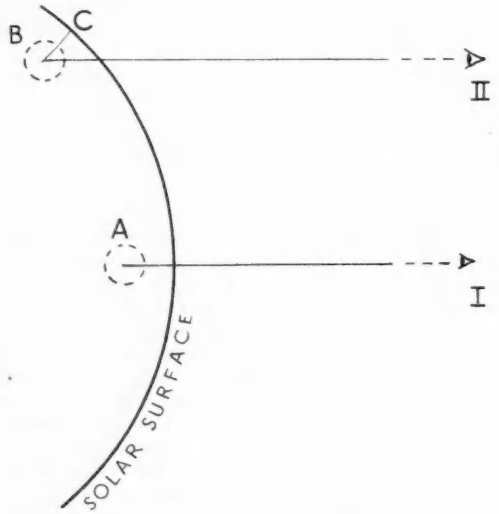


FIG. 2.—Sunspot group and solar granulation.

These lengthy instruments cannot be mounted in a movable tube as stellar telescopes are; they are usually fixed, and the sunlight is fed into them by means of a pair of mirrors, an arrangement known as a coelostat. The primary mirror is mounted on an axis parallel to the axis of the earth and turns to follow the sun, but at only half the rate of rotation of the earth. The result, in accordance with the well-known rule that when a mirror is turned the reflected beam is turned through twice the angle through which the mirror is turned, is that the reflected beam of sunlight comes off the moving mirror in a constant direction. It is then received on a secondary mirror, which, although adjustable for the particular circumstances of observation, is left fixed through each period of observation in such a direction that it sends the beam into the fixed telescope. An instrument of this type showing the coelostat mirrors is shown in Fig. 1. It may be noted that similar instruments called siderostats are used for observation of the sun during total solar eclipses, although in this instance, since the observations are confined to a single day when the sun is in a particular part of the sky, it is possible to dispense with the secondary mirror and to use a single moving mirror to reflect the sunlight into the fixed telescope tube.

When the sun is observed through a solar telescope two features of the image at once strike the eye. In the first place the sun's disc is seen to be darker at the edge than at the centre. In the second place the whole disc is seen to be covered with a uniform fine mottling called granulation (Fig. 2) which changes from minute to minute. This darkening towards the edge, or limb, of the sun as it is called, is of considerable importance in the investigation of conditions in the outer layers of the sun. As we have seen, the sun is a gaseous body, and gases are to some extent transparent. In the case of the metallic vapours and gases which compose the outer layers of the sun it is probable that the transparency is such that there is a visibility in the material of something like twenty to fifty miles (the exact figure is not known). Assuming then that the observer can see into the sun for a distance of twenty miles it is easy to see how the darkening towards the limb arises. If the observer is looking at the centre of the sun's disc he can see into the surface for a distance of twenty miles (Fig. 3), i.e. to a level twenty miles beneath the topmost layers. When he looks at the edge of the sun his line of sight strikes the solar surface at an angle. He can probably still see into the sun for twenty miles, but now this distance is at an angle to the solar surface, and the region which he is actually observing lies not twenty miles below the surface, but some smaller distance depending on the angle at which his line of vision cuts the solar surface. As we have seen, the temperature below the sun's surface increases with depth, so that in the second case the region which is seen, being nearer the solar surface, is also



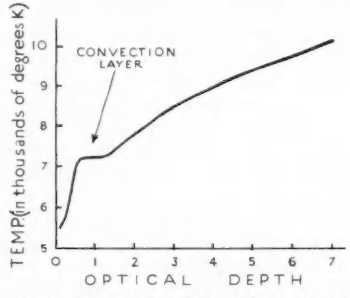


FIG. 3.—(*left*). Observer 1 looking at the centre of the sun receives light from region *A* at, say, 20 miles below the surface; observer 2 looking at the edge of the sun receives light from *B*, also 20 miles below the surface along the line of sight. The real depth of region *B* is only *BC*, which is less than 20 miles. Since the temperature increases with depth below the surface, region *A* is hotter than region *B*, and sends more light to the observer. The centre of the sun therefore looks brighter than the edge, or limb. FIG. 4.—(*above*). Variation of temperature with optical depth below the solar surface deduced from darkening of the solar disc towards the limb. (*After H. H. Plaskett.*)

at a lower temperature. It is both a familiar fact of observation, and, in more precise form, a law of physics, that the higher the temperature of a body, the more light and heat it emits from each unit area of surface. It follows then that when the observer looks along an inclined line, the amount of light coming to his eye along this line is less than when the line of sight cuts the sun's surface at right angles, as it does when the centre of the sun's disc is observed. This is the explanation of the darkening of the sun's disc towards the limb. Observations have been made of the rate of darkening across the surface in light of different colours, and it has been found possible to deduce from these observations the rate at which the temperature increases below the solar surface. As we have seen the limb is darker than the centre, but the actual *rate* of darkening depends on the way in which the temperature increases with depth in the sun's outer layers. The deduction of the rate from the observed darkening is not a very certain process for a variety of reasons, and in addition, the rate can only be deduced, not in terms of actual distances but in terms of what is called optical depth. This term may be understood by the following analogy. Suppose we consider fog (the sun's atmosphere is after all a sort of very hot fog). Then we may say either that the fog bank is a mile thick, or that, for example, it is so thick that only 50% of the light going in at one side gets out at the other. The second specification is less precise than the first, since it wraps up together the two specifications, the density of the fog and the thickness of the fogbank. The circumstances compel us to specify our results in terms analogous to this latter, less precise, alternative. We cannot say that at 50 miles below the sun's surface the temperature is, say, 7000° K. We can say that at a depth such that the amount of solar gases above is such that, say, 50% of the light gets through, the temperature is say, 7000° K. Astronomers use the term 'optical depth' to specify distances in this sort of way. An optical depth of 1·0 means $1/e^{*}=37\%$ of the incident light will pass directly through; an optical depth of 2·0 corresponds to a transmission of $1/e^{2}=13{\cdot}5\%$; optical depth 3·0 to $1/e^{3}$ or a transmission of 5% and so on. It should be noted that this system is applied to a direct beam of light going through the fog. The light which is absorbed is not lost but turns up in the form of scattered light giving a general haze of illumination.

Results of an investigation of the variation of temperature with optical depth are shown in Fig. 4. As will be seen, the temperature rises with topical depth below the surface, but in one region remains stationary. It now seems certain that this region of stationary temperature is a layer in which the gases of the sun, instead of lying quietly layer on layer are actually in motion. Lumps of gas rise up from deeper levels to the top of this *convection layer* as it is called, and then sink back. It is almost certain that these moving lumps of gas are to be identified with the mottling or granulation observed on the sun. Each granule lasts at most a few minutes before disappearing, so that it seems probable that each cloudlet of gas breaking away from the lower level takes several minutes to rise up through the convection layer and to reach the top.

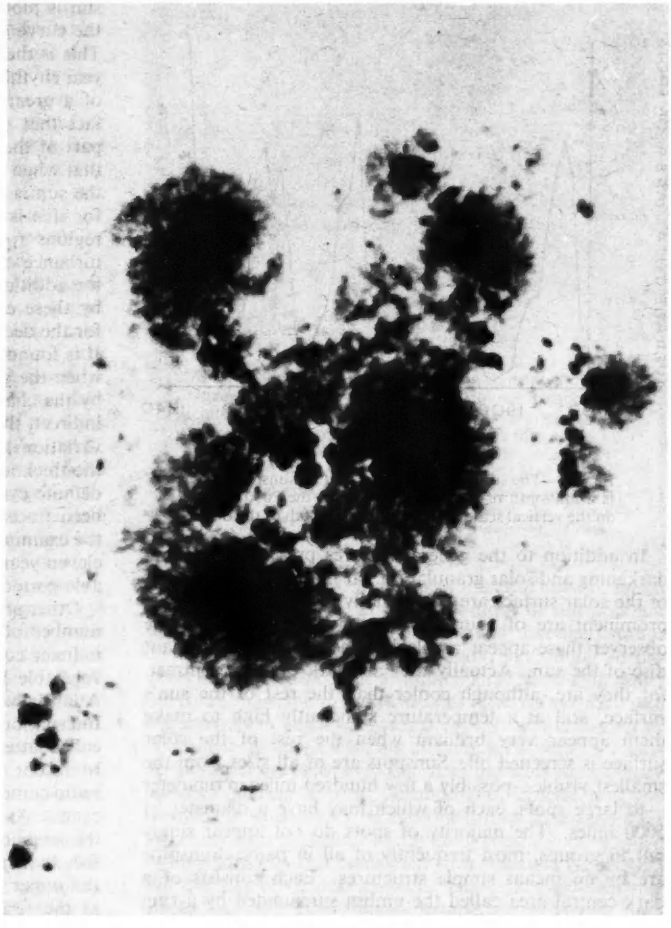


FIG. 5.—Sunspot group.

Developments of studies of this kind are likely to lead to very great advances in our knowledge of the variation of conditions below the solar surface and to a fuller understanding of the very difficult problems presented by the behaviour of the sun's outer layers. It must be noted that these studies are only possible because the sun represents a visible disc, from which small areas can be picked out for separate observation. In the case of every other star we can only observe the total light which comes to us from all parts of the star's disc, so that the information deducible is correspondingly reduced.

* e is the number 2·718, which occurs frequently in all branches of mathematics.

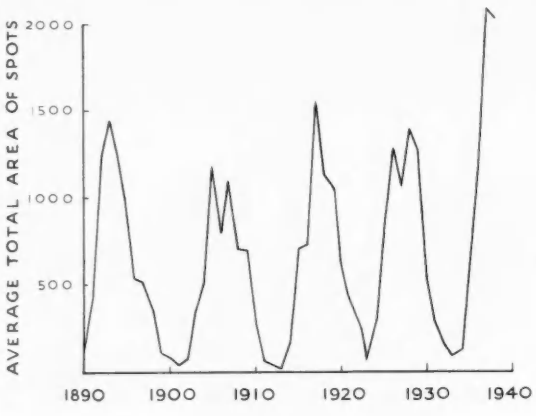


FIG. 6.—The sunspot cycle. The unit of sunspot area is a millionth of the sun's disc; thus the 2000 point on the vertical scale corresponds to 1/500th of the disc.

In addition to the general features presented by limb-darkening and solar granulation, far more striking features of the solar surface are occasionally to be seen. The most prominent are of course the sunspots. (Fig. 5.) To the observer these appear as black areas against the brilliant disc of the sun. Actually they are dark only by contrast, for they are, although cooler than the rest of the sun's surface, still at a temperature sufficiently high to make them appear very brilliant when the rest of the solar surface is screened off. Sunspots are of all sizes from the smallest visible—possibly a few hundred miles in diameter—to large spots, each of which may have a diameter of 5000 miles. The majority of spots do not appear singly but in groups, most frequently of all in pairs. Sunspots are by no means simple structures. Each consists of a dark central area called the umbra surrounded by a ring of intermediate brightness called the penumbra. Closer observation shows that the umbra is often overlaid by long filaments of bright gaseous material extending over the spot from the general bright solar surface (often called the photosphere).

Periodicity of Sunspots

Direct visual observation of sunspots reveals remarkable properties, the most striking of which is their periodicity. The chance of finding a sunspot on the sun is by no means constant. At some times the sun is rich in spots; at others days may pass without the appearance of a single spot. It was found by Schwabe of Dessau as long ago as 1843 that there is a definite periodicity of sunspots, although the recurrences are by no means uniformly spaced in time, nor is the number of spots found at the peak of the cycle constant from one cycle to the next. These irregularities make it extremely difficult to predict in advance the course of the variation in numbers of sunspots, and although many attempts have been made this problem still remains to be solved.

If the area of sunspots relative to the total area of the sun is plotted in the form of a graph it will be seen that the curve shows a peak at intervals of just over 11 years. This is the famous sunspot cycle (Fig. 6), and the eleven-year rhythm which it establishes is reflected in the variation of a great many terrestrial phenomena. In spite of the fact that the occurrence of a sunspot replaces a bright part of the atmosphere by a darker region, it is probable that when sunspots are abundant the total radiation from the sun is greater than when they are sparse. The reason for this is that, by way of compensation as it were, the regions round sunspots are regions of exceptional disturbance on the solar surface and it is probably true that the additional light, particularly ultra-violet light, emitted by these extra luminous regions more than compensates for the decrease due to the presence of the dark spot area. It is found that a time of sunspot maximum is also a time when the growth of plants and trees is slightly stimulated by the change in the solar radiation (the effect is mainly indirect, through the climatic changes resulting from solar variations), and this can readily be detected by observing the thickness of the tree rings in old trees, which shows a definite cycle in a period of eleven years. This cycle has been traced back for hundreds of thousands of years by the examination of fossil trees, and it is clear that the sun's eleven-year cycle has been in existence for a very considerable period of time.*

Other phenomena which show a similar variation are the number of fur-bearing animals in Canada, probably an indirect consequence of the change in the abundance of vegetable life, and the number of icebergs in the North Atlantic which have been the subject of study by the International Ice Patrol ever since the sinking of the *Titanic* called attention to the need for an ice warning service. In recent years the growth of long-distance short-wave radio communication has focused attention on the sunspot cycle. As already mentioned, the possibility of radio transmission round the curve of the earth depends on the fact that radio waves are reflected from ionised layers in the upper atmosphere of the earth and these layers exist as the result of the absorption by the air of the ultra-violet light from the sun. The intensity of this light varies with the sunspot cycle and, in consequence, the behaviour of the ionised layers also shows a variation, compelling a choice of different frequency bands at different times

* The technique of tree-ring analysis whereby the geologist uses the periodic variation in tree-ring width to establish a time scale was described in Professor Zeuner's article "Time and the Geologist" in the April 1946 issue.

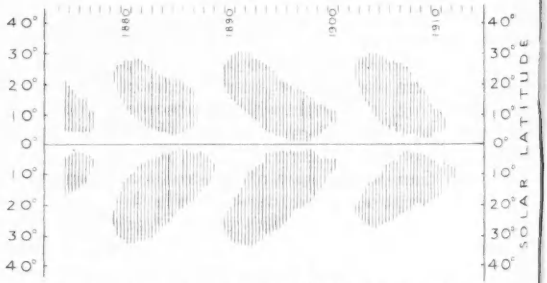


FIG. 7.—The butterfly diagram: if the latitude of each spot on the sun is plotted against the date of appearance the plotted points occupy the shaded areas.

during the cycle. Since these layers tend to decay during the night, there is also a variation in radio conditions as between the illuminated side of the earth and the dark side.

The sun is rotating in a period of 24·7 days, its axis being roughly perpendicular to the plane of the earth's orbit round the sun. We can therefore define an equator on the sun, corresponding to the equator on the earth, and this imaginary line, as seen from the earth, is practically a straight line drawn through the centre of the sun's disc as we see it. We can similarly define on the sun a system of parallels of latitude, at constant distances north or south of this equator, just as we can on the earth.

Many sunspots are comparatively short lived, but a considerable number of the larger spots last a sufficient length of time to be carried round as the sun rotates and to make more than one appearance. These appearances are separated by a time interval of 27 days, which is rather longer than the time of rotation of the sun due to the fact that the earth has moved in the interval. Pairs of sunspots are usually inclined at a small angle to the solar equator, and are distinguished as the leader and follower spots, the leader being ahead in the direction of solar rotation. As time passes it will be seen that the following spot of a pair tends to catch up on the leader, and the inclination of the pair to the solar equator changes. The most striking feature of all is, however, the range of latitude in which sunspots appear. They appear mostly in the latitude range from 30 degrees to about 7 degrees north or south of the solar equator. At the beginning of a sunspot cycle the first spots appear in relatively high latitudes in small numbers. Later, as the number of spots increases, the latitude of appearance becomes smaller until, at about five years after the beginning of the cycle, the spots are appearing in maximum numbers over a fairly wide range of latitude. As the number of spots decreases with the waning of the spot cycle, the latitude of appearance becomes smaller until, at the end of a cycle, a few spots of the old cycle are appearing near the equator at the same time as the first spots of the new cycle are appearing in high latitudes. If the spots are plotted according to latitude of appearance and time they lie in areas having the remarkable shape illustrated in Fig. 7, a diagram due to Maunder and known as the 'butterfly' diagram.

Bjerknes's Theory

The explanation of the existence of the solar cycle is still obscure. It is as if the sun were a variable star with a period of eleven years. Several attempts have been made to explain the periodicity. The most famous is that due to the Swedish meteorologist, Bjerknes, who supposed that beneath the solar surface a complicated system of gas movements was taking place, having the form of long tubes of circulating matter, which occasionally broke surface and revealed themselves as a pair of areas, each being supposed to be the open end of the broken tube.

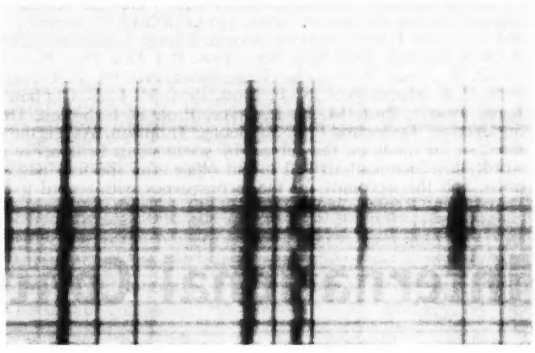


FIG. 8.—Iron lines in spectrum of a sunspot showing magnetic effects. The magnetic field splits each line into three components. The spectrum is photographed through an apparatus which divides it into strips in which different components of the split lines are transmitted. This gives the split lines a castellated appearance which makes the effect more apparent and more readily measurable. (*From "The Sun", by Abetti; reproduced by courtesy of the publishers, Crosby Lockwood & Son*).

Certainly large-scale movements of material must be taking place in the sun, since from observations of sunspots and by other means it has been established that the rotation of the sun is not that of a solid body, but similar to that observed in planets such as Jupiter and Saturn, in which the rotation period in high latitudes is far slower than near the equator. For example, near the poles the rotation period of the sun is about 34 days as compared with 24·7 days at the equator. However that may be, Bjerknes's theory, although not in a form permitting of crucial test, nor completely satisfactory, is the one which at the moment holds the field in default of anything better.

An additional fact connected with sunspots is that they are the seat of intense magnetic fields. It is known that a source of light in an intense magnetic field gives a spectrum in which the lines are displaced or split as compared with the spectrum of the same source in the absence of a magnetic field. This *Zeeman effect* as it is called has been used to detect the magnetic field of sunspots (Fig. 8), and fields of an intensity of many thousands of times the intensity of the earth's magnetic field have been revealed. It is usually found that of the two spots of a pair one will behave like the north-seeking pole of a magnet and the other like a south-seeking pole. During one sunspot cycle it will be found that all the pairs of spots occurring in, say, the northern hemisphere of the sun will have the leader spot a north-seeking pole. In the next cycle the opposite will be true. In reality, therefore, the spot cycle which has to be explained is not the simple eleven-year cycle suggested by the numbers of spots visible, but twice that period.

(*To be continued*)

Within a few days of the announcement of the setting up of the Atomic Scientists Association in Britain this memorandum on the international control of atomic energy was released by the Association. Bearing the signatures of nineteen famous scientists, all of whom were engaged during the war on some aspect of atomic research, it had previously been submitted to the United Nations Atomic Energy Commission. The signatories were: Prof. P. M. S. Blackett, Prof. Max Born, Prof. P. I. Dee, Prof. P. A. M. Dirac, Prof. N. Feather, Dr. O. R. Frisch, Prof. E. A. Guggenheim, Prof. W. N. Haworth, Prof. H. S. W. Massey, Prof. P. B. Moon, Prof. N. F. Mott, Prof. M. L. E. Oliphant, Prof. F. A. Paneth, Prof. R. E. Peierls, Prof. M. H. L. Pryce, Prof. F. E. Simon, Dr. H. W. B. Skinner, Prof. Sir Geoffrey Taylor and Prof. Sir George Thomson. As it is the most significant pronouncement so far made on the subject by scientists in Britain, we publish it in full. One last word: this document arrived in our office after the first pages of this issue had gone to press, and this accounts for the inconsistency with regard to the name of the U.S. State Department Report, which is called the Lilienthal Report in our 'Progress of Science' section.—ED.

International Control of Atomic Energy

ATOMIC SCIENTISTS' MEMORANDUM TO U.N.O.

One of the first tasks confronting the Provisional Committee charged with the formation of an Atomic Scientists Association in Great Britain was the study of the most effective means of international control of atomic energy and the submission of the conclusions reached as a result of this study to the United Nations Atomic Energy Commission. A document embodying these conclusions was prepared but we then received copies of "A Report on the International Control of the Atomic Energy" issued in Washington on March 28 by the U.S. State Department. This report, which will be referred to subsequently as the Acheson Report, contained the conclusions reached by the Board of Consultants appointed by the U.S. State Department's Committee on Atomic Energy and represented a much more comprehensive study of the problem than was possible for us. In many respects the conclusions reached by our committee were similar to those of this American report, and in fact the Acheson report contains all the proposals for the control of atomic energy that our committee considered essential.

In spite of this it still seemed worth while for us to issue a statement embodying the findings of our committee and to indicate the type of reasoning which had led us to make our recommendations. This statement as given below is substantially that prepared by our committee independently of the Acheson report. It has, however, been extended slightly to indicate our support of certain specific recommendations made in the Acheson report that had not been included in our original recommendations.

I

There is universal agreement about the urgency of the problem of the control of atomic energy and of avoiding a war with atomic weapons. We believe, however, that if there were another war between major powers it would be impossible to prevent the use of atomic weapons or other novel weapons of mass destruction and that therefore the problem of preventing an atomic war is identical with the problem of preventing any war.

It is, however, also clear that steps towards this end are unlikely to succeed unless there exists machinery for ensuring that atomic power cannot be misused.

The ideal solution might well be a world state in which there existed no sovereign nations which could wage war against each other. It would, however, be futile to wait for the realisation of this before attempting to institute a control scheme. We believe, however, that it is possible to achieve a measure of co-operation between nations and to establish an atmosphere of confidence, based on the experience of collaboration and of the satisfactory operation of joint projects, which will eliminate the risk of war.

For this it is necessary that nations should waive their sovereignty to the extent necessary to permit agents of U.N.O. to inspect equipment and resources within their territory for the purpose of atomic energy control. This step, in itself, is likely to make an important contribution to international confidence and, on the other hand, it is hard to see how any scheme that stops short of this can give hope of success.

II

Various opinions have been expressed about the nature of the best control scheme. Broadly speaking, one can think of five schemes representing different degrees of interference with the free use of atomic energy; while a choice between these is governed by factors some of which we, as scientists, are not qualified to judge, we would like to discuss them and show that, on purely technical grounds, one of them (viz. scheme (iv)*B* below) seems to us greatly preferable to the rest.

(i) The most drastic step would be to stop all research and development in nuclear physics and destroy all existing installations. Most of us do not believe this to be a realistic idea. Apart from harm done by limiting the expansion of human knowledge to such a drastic extent, the kind of inspection that would be necessary to ensure compliance with this would meet with prohibitive difficulties and would, in addition, tend to stifle scientific research of any kind and would lose to the world many beneficial developments.

(ii) Next, one might not interfere with research and development, but prohibit the erection and operation of large-scale plants capable of producing active materials in militarily significant amounts. This would not necessarily rule out small plants producing material for medical and chemical research and for other applications of tracer elements, but it would rule out any plants for the utilisation of atomic power. This would again mean the loss of what may turn out to be a most useful application of atomic energy, particularly in remote areas and for

SUMMARY OF RECOMMENDATIONS

This summary is taken verbatim from the Atomic Scientists Association's memorandum, which makes the following recommendations:

1. That an attempt be made immediately to obtain an international agreement by which the use of atomic energy, the distribution of the essential raw materials for it, and the erection and operation of plants designed to produce or capable of producing active materials would be strictly controlled by the United Nations Organisation.
2. That this control be implemented by a system of inspection which would give inspectors appointed on behalf of U.N.O. the right of access to any place, plant or institution in any country for the purpose of ascertaining that there exist no sources of supply, plants or installations for atomic energy, other than those approved by U.N.O.
3. That all major sources of raw materials and all major production plants be handed over to U.N.O. and be operated (possibly by national contractors) under international management boards responsible to U.N.O. and guarded by men also responsible to, and appointed by U.N.O.
4. The United Nations Atomic Energy Commission should undertake the construction and operation of new large-scale plant for the production of fissionable material. These plants should be so distributed throughout the world as to ensure that if any nation should seize control of the plants operating in the area in which its own armed forces are predominant the remainder of the United Nations would jointly possess an overwhelming superiority in the production of fissionable material.
5. That the disposal of active materials produced in such plants and the research, development, and production of atomic explosives be reserved to U.N.O. and that any bombs made in that way, or the bombs made prior to the operation of this scheme, be kept in stores distributed throughout the world and operated as described under (3).

   This does not imply that the signatories regard the atomic bomb as a desirable or suitable weapon for carrying out the policing functions of the U.N.O. In the present state of world apprehension, however, it seems necessary that atomic bombs should be produced and controlled by an international authority, to prevent any ill-disposed nation holding the threat of atomic warfare over the peace-loving nations of the world. When, however, the control authority is functioning effectively, it should be possible to envisage the cessation of the production of atomic weapons and the destruction of existing stocks. Atomic explosives could then be used for peaceful purposes only.
6. That as the scheme described above becomes effective, the existing secrecy rules be lifted, starting forthwith with the release of all basic scientific information, and that eventually all research and development be carried on freely and openly, with a duty to report to U.N.O. any significant results, which will, in general, also be published.
7. That the free movement and interchange of all scientists, including those working on atomic energy, be permitted and encouraged to the fullest extent.
8. In the implementing of the above proposals we are impressed with the feasibility of the recommendation made in the Acheson Report of the division of atomic energy activities into 'safe' and 'dangerous' activities and consider that an approach of this kind gives promise of an effective control of atomic energy developments together with a minimum encroachment of the national sovereign rights of the nations.

countries whose natural sources of power are insufficient. Even so, it might be considered that this price was worth paying for the abolition of war. However, the inspection required to enforce such a scheme would only be effective if it aimed at discovering, in addition to actual plants, the preparation of parts for such plants or the production of the special raw materials or materials of construction that such plants require. Even if it were successful, it would break down in the event of war, since experience has shown that it was possible during wartime to complete all the research, development and erection of plants in time to have an effect on military operations. It is evident that this is all the more possible now that all the fundamental problems have been solved.

(iii) The alternative is to allow large-scale plants, including power plants, but to prohibit the manufacture of bombs or of plants for their fabrication. In this case, as in the previous one, it is clear that if war is unavoidable, atomic weapons will be used, and here the delay between the outbreak of war and the use of atomic bombs will be substantially shorter than in scheme (ii). The scheme would still, however, prevent any nation from acquiring a sufficient store of bombs to cripple an opponent by a surprise blow, as long as the inspection system is functioning properly. This inspection would have to include a particularly strict accounting for the active materials which are necessarily produced as by-products in large power plants. This scheme is made somewhat easier by the possibility, published recently in the United States, of 'denaturing' active materials. In addition to strict control of the output of any declared large-scale plants, the inspection system would have to watch for the existence of illicit plants operated from undeclared sources of uranium or possibly other materials. But this feature is common to all control schemes. In one respect scheme (iii), as well as the preceding ones, contains an element of danger in that it places a very heavy reliance on the complete efficiency of inspection. If any country could evade the inspection and secretly obtain control over enough material to make a substantial number of bombs, it would

then find itself temporarily in an unassailable position, since, in the absence of bombs anywhere else, it would not have to fear retaliation by atomic weapons.

It is a common feature of schemes (i) to (iii) that if they are completely successful they would still leave the problem of preventing wars where it was before the invention of the atomic bomb, and unless this problem can be solved completely in other ways there still remains the possibility of war breaking out, which, for the reasons we have given, we believe would inevitably lead to atomic warfare.

In this connexion, however, one should remember that the very existence of an inspection scheme would help to restore collaboration and confidence between nations and would, in this indirect way, make an important contribution to the general problem.

(iv) The next possibility, which we consider far preferable to the others, would be to continue the operation of large-scale plants, provided, however, that such operation and production will be carried out exclusively on behalf of, and under the control of U.N.O., and to reserve to U.N.O. the right to produce and store bombs, if desired. This might appear necessary during a transition period before it is felt that mutual trust between nations has been established to a sufficient degree, but it should be understood that if such bombs are to be made the purpose would not be to serve as a general police weapon for U.N.O. but merely to provide the possibility of retaliation against an aggressor who, in some way or other, has succeeded in making or acquiring atomic bombs.

A. One might think of doing this in a single special territory set aside as the property of the United Nations and to prohibit the manufacture of atomic bombs elsewhere, but we believe that this would lead to insurmountable difficulties, for two reasons. One reason is that unless one wants to deprive all nations of the benefits of atomic power plants, the situation in respect of inspection anywhere outside U.N.O. territory would then again be the same as under scheme (iii). The second reason is that the existence of a small territory containing the store of all available atomic bombs would be regarded as a potential threat by any nation who believed that the countries located in close proximity to the territory and possessing strong armies might intend to seize control of this territory.

B. An alternative form of this scheme, which we prefer to support, would be to have plants and stores scattered throughout the world, located in several countries whose industrial resources make the construction of such plants possible. They would not, however, be owned by the countries concerned, but the countries would operate them as contractors for the United Nations. The plants would be managed by representatives of the United Nations, who would not be exclusively drawn from the citizens of the country in which each plant is located and who would frequently be transferred from one country to another. The plants would be guarded by a small body of guards serving under similar conditions. Their function would not be to defend the plant against a determined attack from the surrounding country, but they would merely ensure that it was not possible to seize control of it without a deliberate and flagrant act of force. Even in this event, the United Nations would still have available the plants and stores in all other countries, which would still constitute a threat of immediate retaliation. It would be essential for the success of this scheme to have such plants in as many countries as possible, and it would probably add to safety if the stores of bombs were fairly widely distributed within each such country.

This scheme would probably make it necessary that in general major power plants should also be owned and controlled by the United Nations: In view of the possibility, however, of operating a power plant by the use of denatured material without at the same time producing fissionable material that could be used for bomb production it may be possible to issue licences for the operation of independent power plants using denatured fissionable material, if the control commission was satisfied that the nature of such a plant would prevent the misuse of the material it contains and produces.

With the exception of such cases, the operation of any plant capable of producing atomic energy or active materials would be prohibited and compliance with this prohibition enforced by a system of inspection.

As far as our knowledge goes, this scheme would seem to offer the best chance of ensuring peace and of saving the world from destruction by atomic warfare.

(v) Less stringent than any of the preceding schemes would be a rule permitting individual nations to make atomic bombs, as they are permitted at present, but to require them to declare the nature and extent of their facilities and to limit by agreement the number and capacity of the plants operated within each country. A system of inspection would then be needed to ensure that there are no undeclared plants and that the limitations are being observed. Apart from the question of inspection, this scheme is somewhat similar to the limitation of naval armaments in operation before the last war. It is essentially based on a balance of power, which would seem dangerous in view of our lack of knowledge of the potentialities of atomic warfare and of the possibility of new discoveries. A distribution of plants which, in a certain situation, might appear to provide security for all nations, could, as a result of further developments, turn out to give one power an overwhelming advantage over others.

(vi) The alternative to all these schemes is to do nothing and to let an atomic armaments race develop. This would happen in the event of the Atomic Energy Commission failing in its task of establishing a reasonable scheme of control, and it is hardly necessary to point out the disastrous consequences this would have. We mention this last alternative merely in order to point out that any of the other schemes, whatever their drawbacks, are preferable to allowing this situation to develop.

III

All but the last of the alternatives discussed above require a system of international inspection, and we want to discuss some aspects of this. At the outset it should be realised that no inspection system can be absolutely rigid, just as it is impossible to prescribe to a police department the precise steps which it should take to prevent the occurrence of crimes in civil life and to detect crimes once they are committed. One should compare the work

of the inspectorate to that of detection of crimes, rather than to an organisation of customs inspectors controlling limited and definite channels of transport.

The method of inspection should be directed, on behalf of U.N.O., by a body containing scientists actively engaged in the further research and development of atomic energy and capable of re-orientating inspection methods as the technical situation changes. Their instructions should be carried out by a force of inspectors who will, of course, be responsible directly to U.N.O.

These inspectors must, in the first instance, have access to all known sources of the raw materials essential for atomic energy and to any plants known to be in existence for the utilisation of atomic energy or the production of active materials. In addition, however, they must have access to any factory, whether privately owned or government controlled, and to any mine or store of raw materials, in order to ascertain that there exist no illicit sources, plants or stores.

Admittedly this represents drastic interference with the present freedom of individual governments or individual firms to keep their operations secret, but it does not necessarily mean the abolition of industrial secrets as such. The inspectors who visit, say, an aircraft factory, would normally possess technical knowledge not on aircraft construction but on atomic energy plants, and their sole purpose would be to ascertain that the factory does not contain secret facilities for producing atomic energy or for manufacturing equipment for this purpose; it would be quite as improper for them to communicate details of the design of aircraft that they have seen as this is now for factory inspectors employed for various purposes by governments. The inspectors would not attempt to carry out what, in manufacturing practice, is known as 100 per cent inspection. Instead they would follow up significant clues and they would be advised by the organisers of the inspection system of any technical features connected with the existing processes which would be likely to lead to the disclosure of illicit plants. They would, however, carry out a complete check on the distribution of essential raw materials from known sources of supply and on any active materials produced by, or extracted from known plants.

It is clear that a large number of men and women would have to be employed, but the number would be small in comparison with the numbers at present employed on civil police duties. Only a small fraction of these men need be skilled scientists.

It is necessary to ensure that the task of the inspectors should be made as simple as possible. To bring this about the recommendation made in the Acheson Report referred to above offers a useful starting-point. This report suggests that all activities associated with the production of atomic energy should be classified into 'dangerous' activities—carried out exclusively by the United Nations Atomic Energy Commission—and 'safe' activities—carried out by national or private bodies under licence to the United Nations Atomic Energy Commission.

The dividing line between 'safe' and 'dangerous' categories would need to be defined with great care and be capable of re-definition from time to time to allow for the possibility of new developments.

It is suggested in the report that all processes involving the mining of uranium and thorium ores and the production of 'denatured' fissionable material would be classified as dangerous. Small-scale research activities using 'denatured' fissionable material would certainly be classified as safe.

The definition of legal and illegal activities along lines such as these should go a long way toward simplifying the tasks of inspection.

IV

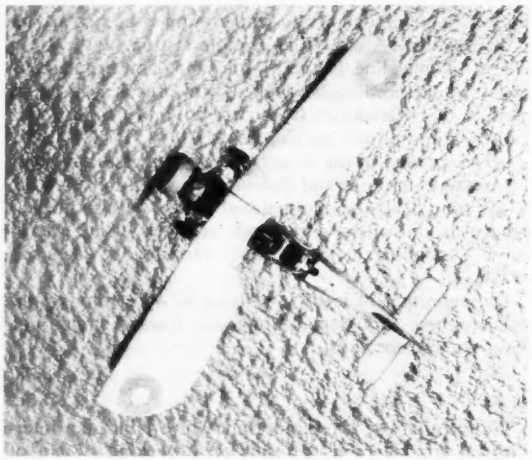
We have stressed the importance of establishing international confidence as a result of a working system of inspection, and in this connexion the free movement and exchange of scientific personnel is a very important factor. We believe that this single measure would go a long way towards relieving the present difficulties. There is no doubt that scientists of all nations will collaborate if they are permitted by their governments to do so. It might be argued that full international collaboration of scientists existed before the last war and did not prevent it, but it must be borne in mind that as a result of recent developments, and of the development of atomic energy in particular, scientists now have a clearer realisation of their responsibilities and easier access to their Governments, and if they were permitted to associate they would be able to contribute more to international understanding than they could do in the past. We wish, therefore, to urge very strongly immediate measures to restore and encourage the free exchange of scientists.

V

In conclusion we wish to pledge the active support of the signatories of the present statement to a scheme similar to the one recommended by us. We would again point out that this line of approach is similar in principle to that embodied in the report of the Acheson Committee although that report represents a much more comprehensive study of the whole problem.

We, therefore, wish to go on record also as in support of the recommendations made in the Acheson Report and to urge on the United Nations Atomic Energy Commission the necessity for the adoption of some control mechanism based on them.

It is our conviction that practically all scientists in the world will likewise be ready to do their utmost to help in working out the details and in implementing such a scheme.



(*Left*) The Swordfish, the only aircraft on either side to go right through the war without modification. (*Right*) The De Havilland Sea Vampire F. Mark I, ready at the end of the war. Powered by a Goblin II turbine, its speed in normal fighting trim was put at 540 miles an hour. (*Courtesy of "The Aeroplane".*)

Aircraft Types of World War II

R. G. WORCESTER

THE pre-jet era culminated in the development of a great variety of types which decided the air strategy of World War II. How many of them does the reader remember after nearly one year of peace?

In the early days it was the Bristol Blenheim and Fairey Battle that were mostly in the news while the dreaded Ju 87 Stuka held Europe in fear. The Avro Anson with its little Cheetah engines was doing fine work with Coastal Command—although the first German victim was actually claimed by a naval Blackburn Skua. A unique aircraft was the Fairey Swordfish of the Fleet Air Arm, which was flying long before the war and continued right through the German war without major modifications; its successor, the Albacore, did good work but never achieved the fame of the Swordfish.

Soon after Dunkirk followed the Battle of Britain, which was won jointly by the eight Browning guns of the Hawker Hurricane and the Supermarine Spitfire. The early Spitfire was the beginning of a long line each with improvements to rate it as among the fastest interceptors. The Fleet Air Arm used the Spitfire with minor changes; the Spitfire/Seafire series has now been replaced by the Spiteful and Seafang. The Hurricane was used with a variety of different guns, bombs and other weapons and was superseded by the Typhoon which did such effective work with its rocket projectiles, while the two-seater Defiant fighter left its mark both by day and, later, by night.

The heavy bombers in use at the beginning of the war were the Handley Page Hampden, and—re-engined with Napier Daggers—the Hereford, the Whitley and the Vickers Wellington; meanwhile the Germans were using the equally effective He 111 and the Junkers 88 and Me 110. Their principal fighter was the Me 109, which had roughly the same speed as British types although the engine was rather bigger. As the war progressed the twin-engined bombers gave way to the 25-30 ton class of which there were originally four British examples—the Avro Manchester, which was re-engined and became the Lancaster (the most versatile bomber, able to carry the smallest and the largest bombs together); thirdly was the massive Short Stirling which hammered away at strategic targets before being adapted for towing Horsa and Hamilcar tank-carrying heavy gliders, transport and other duties; lastly there was the Handley Page Halifax, which did great work both in Europe and in the Middle East.

The Germans were employing small numbers of He 177, which were distinguished by the use of two groups of 'double-engines', making four in all, but the aircraft was never a success. The Germans' anti-shipping aircraft was the long-range Focke Wolfe Condor or Kourier which was an adaptation of a former civil airliner. Later, radio controlled glider-bombs were carried by these aircraft. A few six-engined Bv 222 flying boats were seen and one or two were shot down.

Coastal Command was using quantities of lease-lend Lockheed Hudsons, remembered by many people as the Lockheed 14 Transport. The Short Sunderland flying boats were ranging far out into the Atlantic—their basic design was widely known before the war in the Empire flying boats. Perhaps the most efficient of all was the lease-lend Consolidated Catalina twin-engined flying boat.

At this point (1) American aircraft were beginning to appear in appreciable numbers and (2) the Germans started to concentrate on novel weapons. Of the American aircraft, the much publicised Boeing Flying Fortress went through many teething troubles and emerged as an aircraft

B-29 SUPERFORTRESS

AVRO LINCOLN

able to take care of itself in daylight and carry about two tons of bombs. The Consolidated Liberator was generally similar. At this time the medium bombers were providing valuable support for land forces and used extensively on short range missions, of these the Douglas DB7 Boston and North American Mitchell were perhaps the best U.S. types while the Martin Marauder, though tricky to fly, proved itself over Europe. By far the best in this class was the De Havilland Mosquito which could carry two tons of bombs to Berlin as well as being used as night fighter, day fighter, anti-shipping aircraft (with a six-pounder gun), and more recently as a carrier-based fighter-bomber. Useful also against shipping was the tough Bristol Beaufighter with its six machine guns, four cannon and rocket projectiles; alternative loads included a standard British torpedo. A Merlin-engined version—the Beau II—was used for land-based Naval duties, alongside the torpedo-carrying Beaufort. The North American Mustang was officially rated as the best U.S. fighter and was originally built to a British specification and fitted with a Rolls-Royce engine made in America by Packard. The Thunderbolt also did good work but was rather heavy and the Lockheed Lightning with its unusual twin booms was often seen in battle. Army Co-operation types included the Westland Lysander, the Auster and American Tomahawk.

Naval aircraft were handicapped by lack of a 2,000 h.p. engine, and the Royal Navy relied upon the lease-lend Grumman Avenger bomber and Hellcat fighter; also the Vought Corsair fighter. These strike aircraft were supported at first by the Fulmar and Gladiator and later by the Seafire, Barracuda and new Fairey Firefly and Firebrand strike fighter.

After D-Day the Germans were using jet-propelled aircraft in greater numbers than we, and they were on the defensive—almost, in fact, looking for miracles from their fighters. The Me 262 'Swallow' was easily the best fighter and had a top speed of about 530 m.p.h. but only achieved at the expense of manoeuvrability, endurance and durability. The same also applies to the He 162 which, if

DE HAVILLAND MOSQUITO

DOUGLAS DAKOTA

anything, was even more difficult to fly. It was really the promise of the jet fighter rather than the actual performance that was significant up to the end of the war. The Germans had collected sufficient numbers of flying bombs to commence an attack but they were encountered by the new Tempest II and V aircraft, a direct development of the earlier Typhoon, and Gloster Meteor jet aircraft also joined in the chase. Later the Germans used the impressive V 2 rocket with a range of about 200 miles and accuracy of three miles—an outstanding example of German inventive talent.

When the Germans collapsed and the war moved East we found that the most effective weapon was the superbomber, and the Americans were using the Superfortress as well as the B-32 Dominator in small numbers.

The Japs themselves had a few good aircraft, among them the Jack fighter and the twin-engined Betty bomber with its suicide Baka bomb tucked underneath.

The Japanese surrender found the Americans ready to throw in many new types, including the twin-engined Tigercat carrier-based fighter and the Lockheed Shooting Star with a British jet engine made in America, and the B-36 six-engined bomber. We were about to operate the Avro Lincoln super-bomber and the 540 m.p.h. De Havilland Vampire as well as the long-range Hornet fighter and its ship-borne counterpart, the Sea Hornet, and the Hawker Fury I and Sea Fury X. Transport aircraft were vital in all the operations of the war and the Americans were always far ahead of us with large numbers of Douglas Dakota and Skymaster aircraft, and also Liberators and Curtiss Commando transports; American concentration on transport aircraft arose from combined Anglo-American planning. We were using a few Harrows and Bombays and later small numbers of Avro Yorks and Tudor I's were becoming available. Of the flying boats, the Sunderlands were fitted with the more plentiful American engines and were to be replaced by the 10,000 h.p. Short Shetland flying boat. The Americans had also started to build a similar class of boat—the Martin Mars, of 70 tons—but with less power available.

The outstanding trainers were the D.H. Tiger Moth and Miles Magister elementary trainers and the Air-speed Oxford and Miles Master/Martinet for advanced training and target towing. The Harvard was also an excellent type. Britain sets the pace again with the 5100 h.p. Bristol Buckmaster trainer.

REFERENCES

A.E. stands for *Aircraft Engineering*; A.P. stands for *Aircraft Production*.

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PERENNIAL WHEATS

FIFTEEN years ago, at the 'Gigant' State Farm in the Northern Caucasus, the first hybrid wheat was obtained by crossing wheat and couchgrass. That success was the starting-point of our major work on the crossing of cultivated plants with wild varieties.

For thousands of years man has been developing cultivated plants, accumulating properties important primarily to man and not to the plant itself. As a result, cultivated plants have become too tender, and are hardly capable of leading an independent existence. The evolution of wild-growing flora, on the other hand, has been essentially different. For thousands of years these plants have been developing properties that helped them in the struggle for existence and for propagation.

Our aim is to turn to use the contrasting properties and characteristics of these distant relations. And indeed, the crossing of such plants as wheat and couchgrass does produce excellent results.

To blend in a hybrid the important properties of both wheat and couchgrass, thereby creating new forms and species of useful agricultural plants—such is the major and fundamental task which we have set before ourselves.

Now about the positive results we have obtained. To begin with we have discovered five varieties of couchgrass which can be effectively crossed, not only with any variety of wheat, but also with rye, as well as with certain wild species of wheat called *Triticum aegilops*. As a result of hybridisation and subsequent selection, we have bred a number of new varieties of summer and winter wheat. In contrast to common wheat, these new varieties possess complex properties of great importance for agriculture.

I would mention particularly the perennial wheat—a new variety of agricultural plant produced by the hybridisation of wheat with couchgrass. Ten years ago we obtained the first variety of perennial wheat—which, having been once sown, yielded from three to four crops. But as it had a number of shortcomings we refrained from cultivating it on a large scale. Instead, we developed new varieties, which can now be recommended for sowing in any areas of the agricultural zone.

Now we are busy on problems of the speedy reproduction of these remarkable new varieties of perennial wheats.

Within the last three years we have gained yet another victory. We have succeeded in overcoming the resistance of wheat and barley to crossing with another remarkable wild-growing plant belonging to the genus *Elymus*. (In Britain, where it is found on sand dunes, it is called *lyme grass*) The hybrids thus obtained—Wheat-Elymus and Barley-Elymus—are of very great importance indeed. For our results will enable us to breed varieties which will contain 200 or 300 or even more grains to the ear, as against the usual 30 or 40. This achievement will undoubtedly lead to tremendous crop yields. Moreover, we have found a solution for the problem of utilising semi-waste lands, for these can be planted with the new hardy varieties.

ACADEMICIAN NIKOLAI TSITSIN.

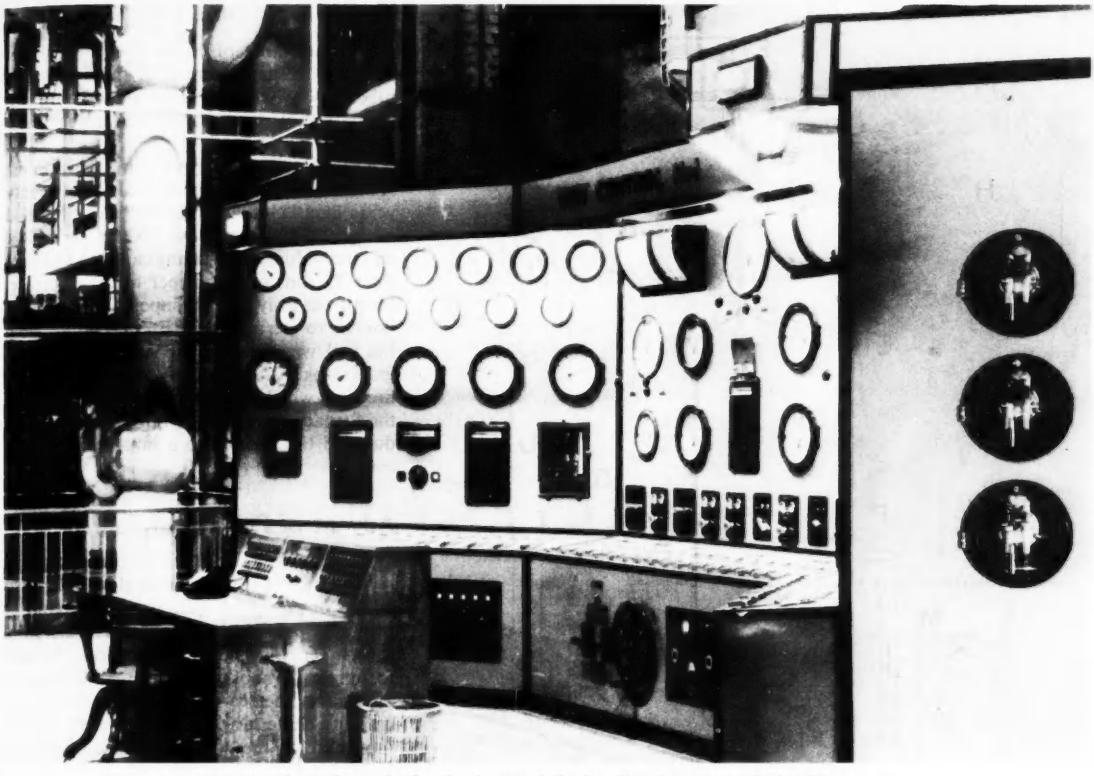

FIG. 1.—Control panel of pulverised fuel fired boiler. (*Courtesy, Bailey Meters.*)

Research and Steam Raising

R. F. DAVIS, M.Sc., M.I.Mech.E.

BRONZE heating vessels having tubular firebars were found in the ruins of Pompeii. The Romans were perhaps the first to appreciate the advantage of dividing the water in a vessel into tubular compartments for increasing the efficiency of transmitting heat to the water. This principle seems to have been lost sight of by the early British boiler-makers, until in 1824 Jacob Perkins, a pioneer of high pressures, built a multi-tubular boiler of hollow cast-iron sections. He was far ahead of his contemporaries, operating his boiler at 500 lb. per sq. in. and forcing the water to circulate by means of a pump.

The first water-tube boiler with mild steel tubes to be developed commercially was a French design known as the Belleville; this was in 1849. Seven years later it was followed by that of Stephen Wilcox, which appeared subsequently, under the joint names of Babcock and Wilcox, almost in its present form. It consists of a bank of straight tubes slightly inclined to the horizontal and connected at either end to forged steel vertical headers or boxes. The water from a large horizontal drum located above the tube bank circulates down into the headers connecting the lower end of each vertical bank of tubes and then, due to the heating and its consequent expansion in the tubes, rises to the higher ends and finally the mixture of steam and water discharges into the same drum above the water level. As steam is drawn off from the top of the drum, water is forced in below at the same rate, so that the water level remains steady. All modern so-called 'ratural circulation' water-tube boilers work on this principle of the thermo-siphon.

Contemporaneous with these early commercial developments of land boilers a multitude of designs were proposed having various—and sometimes fantastic—combinations of tubes and drums. Naval authorities were early to recognise the immense advantage of the compact water-tube boiler compared with the bulky cylindrical type, and adopted the three-drum design (which is still in use), having two lower water drums with a main steam drum centrally disposed above. The tubes running from each of the lower drums to the upper one form an inverted V with the furnace between. The structural and operating features of this design are particularly suited to conditions on shipboard. The Yarrow boiler is a commercial modification of this type. Another three-drum boiler was developed

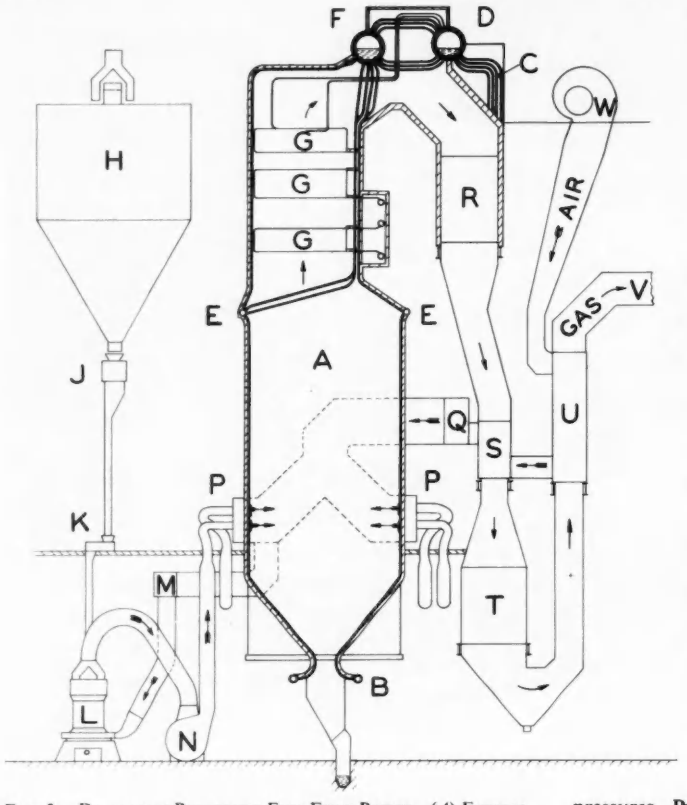

FIG. 2.—DIAGRAM OF PULVERISED FUEL FIRED BOILER—(*A*) Furnace. (*B*) Bottom headers supplying water to the furnace evaporating tubes. (*C*) External downcomer tubes taking the water from the rear boiler drum (*D*), a hundred feet above the basement level, to the headers (*B*). (*E*) Upper headers connected to the front boiler drum (*F*) by riser tubes which discharge the mixture of steam and water into the drum (*F*) where the steam is separated from the water and passes via the upper tubes into the drum (*D*) on its way to the superheater coils (*G*). The water delivered into the drum (*F*) passes via the lower tubes into the drum (*D*) where it mixes with the incoming feedwater before re-circulating down the tubes (*C*).

The coal supply gravitates from the storage bunker (*H*), through an automatic weigher (*J*) and feeder mechanism (*K*), to the pulverising mill (*L*) in the basement. The coal is ground on a horizontal rotating table by three spring-loaded rollers running in contact with the layer of coal, while a continuous blast of hot air from the duct (*M*) dries the moisture out of it and transports the resulting powder, through the medium of the exhauster fan (*N*), to each of the four corner burners (*P*).

After the evaporating tubes in the furnace (*A*) have extracted by radiation more than half of the heat generated by combustion of the fuel, the gases pass over the superheater coils (*G*), which they leave at a temperature of 1000° F. to enter the economiser (*R*), which transfers some of the remaining heat to the boiler feedwater. From the economiser the gases pass through an air pre-heater (*S*), consisting of a number of thin metal plates separating alternate streams of air and gas into layers about half an inch thick. The heat extracted by the air heater is returned to the furnace in the combustion air to the burners (*P*) at 500° F. via the duct (*Q*). (*T*) and (*U*) are further sections of economiser and air heater, finally cooling the gases to 300° F. when they leave by the duct (*V*) to enter the ash precipitator (see Fig. 3). Air is extracted from the top of the building by the fan (*W*) and forced through the air heaters. There are two fans, together handling 150,000 cu. ft. of air (5 tons) per minute at a pressure of 8 inches water gauge. (*Courtesy, International Combustion, Ltd.*)

under the name of Stirling, for land use, in which the arrangement of the drums and tubes is somewhat different, there being two upper steam drums and one lower water drum.

These established types remained almost static in their development until about twenty years ago. Until then boiler pressures had not generally risen above 200 lb. per sq. in. and individual units having capacities greater than 25 tons of steam per hour were rare. Steam was only slightly superheated in these boilers to perhaps 550° F. or 600° F., and the fuel was fired by means of a travelling grate stoker—a kind of conveyor belt of firebars, which slowly carried the fuel into the furnace where it was burnt off, and then dumped the ashes into a hopper at the far end.

Advent of Pulverised Fuel

At the close of 1923 a company was formed in this country to exploit the possibilities of pulverised fuel, under the name of International Combustion. This ushered in a new era in steam generation. It was fortunate perhaps that the introduction of pulverised fuel coincided with a vastly increasing demand for electric power, and the inception of the 'Grid'. It also coincided with the realisation that increased thermal efficiency could be gained by operating turbines at higher steam temperatures and pressures. Pulverised fuel caused a gradual revolution in water-tube boiler design, and is now rapidly becoming standard in power stations all over the world.

With the original type of stoker-fired boiler a large amount of refractory brickwork was always exposed to the radiation from the fuel bed, and often curved arches of brickwork were built above it, supposedly to reflect the heat back on to the fuel in order to improve its combustion. It was soon discovered that pulverised coal burned with a much greater intensity due to the tremendous extension of the active surface of the ground fuel; consequently refractory walls had a short life. Gradually boiler tubes were extended into the furnace to protect the walls and, surprisingly, this had no detrimental effect on combustion. The ultimate outcome was a furnace with no refractory at all; thus, the radiant heat boiler evolved.

There are today in the U.S.A. individual pulverised fuel boilers producing over 500 tons of steam per hour. In this country the present trend is towards an upper limit of 200 tons per hour with operating pressures in the 700-1400 lb. per sq. in. range. Steam temperatures, over the higher pressure range, usually exceed 950° F.—the steam is literally red-hot. Researches in many fields have contributed to make these steam conditions possible.

The cross section of a large pulverised fuel fired steam generating unit is shown diagrammatically in Fig. 2. It has an output of 200 tons of steam per hour at a pressure of 1400 lb. per sq. in. and a temperature of 965° F. The dominant feature is the water-cooled furnace which

is 25 ft. square in plan and about 50 ft. high. The walls of this furnace consist of a number of vertical evaporating tubes (3 ins. in diameter) with fins or strips of metal an inch wide welded on either side of them, so arranged that the edges of adjacent fins nearly touch each other and thus form an almost continuous metal face, absorbing radiant heat from the burning pulverised fuel.

A suspension of pulverised coal in pre-heated air is projected into the lower portion of this furnace from nozzles in each of the four corners. The fuel and air enter at a speed of about 120 ft. per second and in such a way that a turbulent vortex motion is produced in the ascending mass of burning coal particles. A boiler of the size indicated in Fig. 2 requires about 25 tons of coal per hour; this is finely ground in the pulverising mills and reduced to an average particle size of $\frac{1}{300}$ inch. After passing over the evaporating and superheating tubes, the products of combustion are still further cooled by passing them through economisers and air heaters. By this means 90% of the net heat available in the fuel is usefully extracted.

All the pre-heated air required for combustion of the coal is forced under pressure through the burners at the rate of approximately 5 tons per minute. Induced draught fans maintain a slight suction in the furnace and discharge the extracted products of combustion to the chimney, but before entering the fans the coal ash, which is in the form of dust, is extracted by an electrostatic precipitator (Fig. 3). The extraction is brought about as the gas passes through a number of vertical metal tubes which are electrically earthed, each tube having a metal wire passing down its centre negatively charged to a potential of 40,000 volts. The solid particles entrained in the gas become electrically charged and are attracted to the tube walls, to which they adhere; they are then removed by a rapping gear that strikes the tubes periodically with hammers, causing the dust to fall into a hopper below. The flue gases leaving the chimney stack are almost imperceptible, 95-98% of the suspended fine ash (or smoke) having been extracted.

Higher Pressures and Temperatures

The operating pressure of boilers in central power stations has risen during the last two decades from a standard of 200 lb. per sq. in. to 900 lb. per sq. in.; even 1400 lb. per sq. in. is not now unusual. Steam temperatures have likewise risen from 600° F. to 950° F. in the same period. The reason for these increases is the desire for improved efficiency. For example, at 600 lb. per sq. in. each 27° F. rise in steam temperature results in a gain of 1%, while doubling the pressure adds a further 4½%.

Early researches on the properties of steam and investigations into thermo-dynamic theory indicated that such improvement could be expected. That this forecast was correct is amply demonstrated by the fact that the average annual thermal efficiency of power stations has improved in the last 20 years from 20% to over 30%—a net gain of 50% more power from the same weight of coal. Other factors have, of course, also contributed.

The first exact measurements of the properties of steam and water were made by Regnault about a century ago. The first system of equations complete and consistent with the laws of thermodynamics were published by Prof.

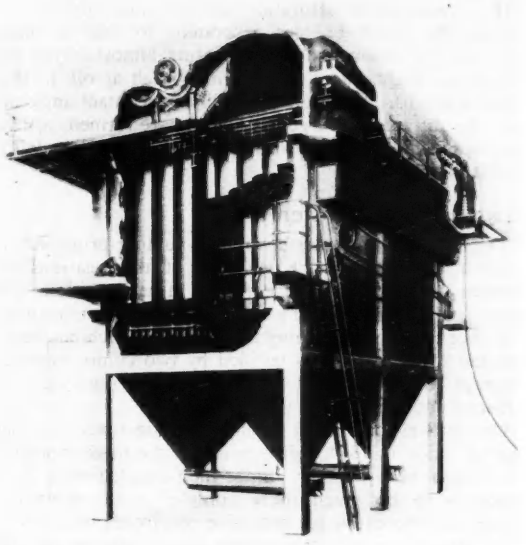

FIG. 3.—Electrostatic ash precipitator. (*Courtesy, Sturtevant Engineering Co., Ltd.*)

H. L. Callendar of the Royal College of Science, and steam tables based on his system were later published by Mollier. In 1915 Callendar published his own steam tables up to 500 lb. per sq. in. and extended them in 1924 to 2000 lb. per sq. in. Callendar devoted the greater part of his life to experimental and theoretical researches on the properties of steam, and they were continued by his son after his death in 1930, who published, in conjunction with Sir Alfred Egerton, another edition of the tables in 1939, extending them to the critical pressure (3206 lb. per sq. in.). Other workers in America and on the Continent also joined in these researches, their work being co-ordinated by international conferences.

Changes in the thermodynamic properties of steam and water with pressure are not the only physical characteristics that interest the boiler designer. As the operating pressure becomes greater, the density of the steam increases and that of the water decreases. The rate of circulation is, therefore, much more sluggish at high pressure, and unless special precautions are taken there is a danger of the boiler tubes bursting due to over-heating of the metal. Thermo-syphonic circulation in water tube boilers has been the subject of much mathematical and practical research.

In this connexion, investigations have also been made into the laws governing the production of steam bubbles at a heating surface, and also the dangerous limiting rate of heat input at which nuclear, or bubble generation of steam changes to the state known as 'film boiling', when a complete insulating layer of steam forms between the metal and the water, causing a sudden rise in the metal temperature, which may be followed by its ultimate failure. The size and shape of the steam bubbles at the heating surface depends on the surface tension of the water and also on the contact angle between the water surface and the tube. The surface tension diminishes

with increase in the saturation pressure, and with it the size of the steam bubbles generated; so that at high pressures the steam and water mixture almost forms an emulsion. Slight traces of impurities, such as oil, in the boiler water can, however, so modify the contact angle at the tube surface that large flat bubbles are formed, which may cause the early onset of film boiling, sometimes with disastrous results.

Laws of Heat Transfer

The laws of heat transfer are the guiding principle of modern boiler design. Knowledge of the relationship between the factors involved were rather nebulous 20 years ago, especially on the side of industrial application, but since then an astonishing amount of research has been devoted to the subject as testified by two comprehensive volumes entirely devoted to its study, one published in America and the other in this country.*

Osborn Reynolds in his original investigations into the flow of fluids, in 1874, first expounded the mechanism of convection heat transfer. Since then detailed study has found it to be much more complex than originally visualised. Recently, the extensive researches of a team of workers in America have shown exactly how the rate of heat transfer from a flowing gas to the tubes in a boiler depends not only on the velocity of the gas and its viscosity but also on the spacing and arrangement of the tubes. In a superheater tube the velocity of the steam is also a controlling factor. The rate of convection transfer to boiler tubes increases directly as the 0·61 power of the rate of cross mass flow or velocity, but unfortunately the resistance to flow increases as the square of this velocity. Generally, therefore, gas speeds are limited to about 50 feet per second, as greater speeds unduly augment the load on the induced draft fan without a corresponding effective gain in the rate of heat transfer.

Where the tubes are widely spaced and in a relatively hot gas zone, a very large proportion of the heat transfer takes place by radiation from the carbon dioxide and water vapour, each of which are present in most products of combustion to the extent of 10% to 15%. It was pointed out by Schack in 1924 that all gases except those that are elements (e.g. oxygen, nitrogen and hydrogen) are effective radiators between certain limits of wavelength at industrial temperatures. Results of investigations made more recently by Hottel enable the boiler designer to calculate fairly accurately the extent of this effect, which in some cases may account for more than half of the total heat transfer from the gas.

In the furnace, or combustion chamber, the gases are fully luminous due to the higher temperature and the presence of burning particles of fuel, together with the cracked hydrocarbons from the volatile constituents in the coal and particles of incandescent ash. The radiation from a cloud of burning particles, such as occurs in a pulverised fuel flame, is very complex, but attempts have been made to analyse it mathematically. Mostly, the boiler designer treats so large a flame as a 'perfect radiator', radiating according to the fourth power of its absolute temperature, applying a suitable absorptivity factor (for the emitted heat absorbed by the evaporating tubes).

The temperature of the gas leaving the combustion chamber can thus be estimated accurately and this is important, since an excessive temperature causes the ash particles to fuse and their subsequent freezing on to the relatively cooler boiler tubes causes what is known as 'slagging'—a gradual building-up which chokes the gas passages between the tubes, so that ultimately the boiler has to be taken out of service. The avoidance of this effect is appreciated when one considers, for example, that power station boilers are expected to be capable of running for at least six months, continuously night and day, at full rating. During the war some stations had temporarily to change to coals having ash of a much lower fusion temperature than that for which their boilers were originally designed, with disastrous results.

[To be concluded

* *The Calculation of Heat Transmission*, by Fishenden & Saunders (H.M. Stationery Office). *Heat Transmission*, by McAdams (McGraw-Hill).

PROGRESS OF SCIENCE—*Continued from p. 167*

making wine as they require no artificial treatment to secure proper fermentation.

The association of bacteria with insects is not always fully realised. Everyone knows the kind of food on which the larvae of houseflies and blowflies thrive, but how many people are aware that the rich growth of bacteria and fungi present in the decomposing material is essential to the development of their larvae? A few years ago sterile maggots were commonly employed in the treatment of infected wounds and osteomyelitis, and the technique of rearing sterile blowfly larvae was brought to a high degree of perfection. It was found that the absence of the normal bacterial flora had to be remedied by supplementing the maggots' diet, in particular with vitamins of the B group.

The odours characteristic of decaying matter and which attract the adult flies are developed in the processes of decay brought about by the bacteria. Ammonia is one of the substances to which houseflies are attracted, and if this substance, at a suitable concentration, is added to a material without potential feeding value to the larvae the flies will be induced to lay their eggs on it. The eggs are laid more abundantly if butyric or valerianic acids are present in addition. Both these acids are liberated in the decay of the kind of organic matter which forms the breeding ground of the housefly.

Incidentally, a similar sort of mechanism appears to operate with some of the insects whose larvae feed on yeast. An example is a beetle called *Carpohilus*, which is a pest in dried fruits; this has been found to be powerfully attracted to stewed fruit only after that medium had been inoculated with moulds or yeast. The chemical substance responsible for the attraction of *Carpophilus* is probably alcohol or acetic acid.

This note takes notice of but one chapter in Professor Brues's book, but the rest of the book is just as entertaining to anyone interested in the feeding habits of insects.

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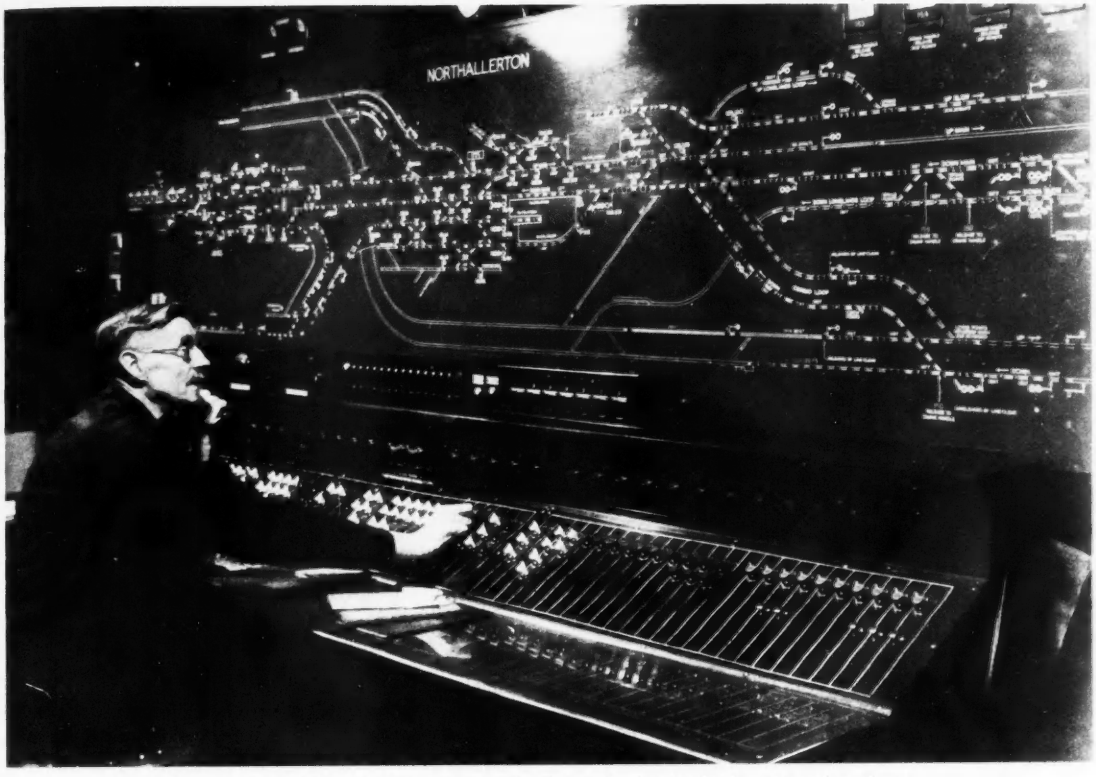


Northallerton, (L.N.E.R.) all-electric power signal-box, showing the signalman operating a thumb-switch. Taking the place of levers, the switches, in turn, operate points and signals shown on the track diagram which is studded with electric bulbs that light up as trains pass over the track. Such signal-boxes give greater safety and speed, as well as enabling large sections of railway track to be controlled by one man. (*Courtesy of Westinghouse Brake & Signal Co., Ltd.*)

Railway Signalling

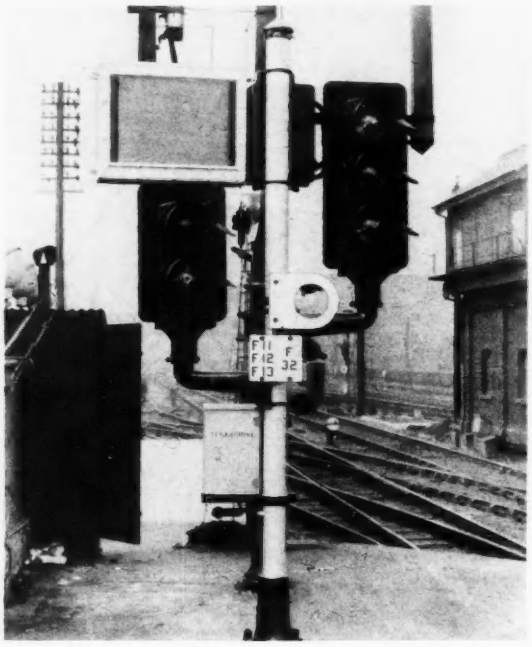
FRANK FERNEYHOUGH

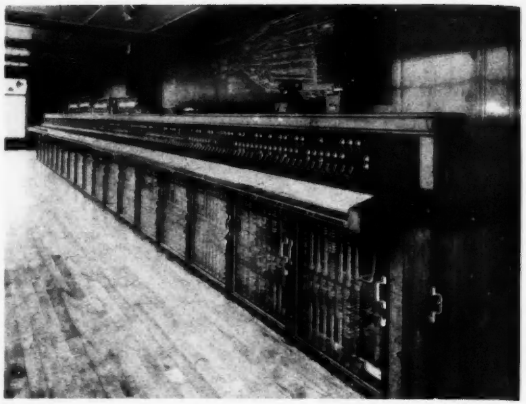
It is a well-known fact that British railways have a higher traffic density than any in the world, but accidents are relatively few. Contributing largely to the safe and rapid movement of trains is the complicated and highly scientific system of signalling in use. From the time when, more than a century ago, a man stood by the line-side waving flags, to present-day, electric signals, the first consideration has been safety. If any new device or system has not measured up to a high standard of reliability, it has immediately been discarded. Many features have to be considered: signalling apparatus must stand up to the elements, should be standardised, and easy to understand and to learn; then their design must allow for the human element, and for unforeseen happenings.

Simply, the principle of railway signalling is this: the line is divided up into sections of varying length from a quarter of a mile to several miles. Each section, at either end of which is a signal-box, is considered blocked until the signalman controlling the entrance to it has first obtained the permission of the signalman at the other end for a train to proceed through it. To save time, however, such permission is given well in advance, so that the train's speed is not reduced unnecessarily.

All messages are sent and received by telegraph. Bell codes are used, and in addition electrical three-position indicators show whether the section is blocked, or clear for the next train, or actually occupied by a train. Telephones invariably supplement the telegraph apparatus, all wires running alongside the railway on ordinary telegraph posts.

Having received permission to allow a train to proceed, a signalman may then pull off his signals to the clear position. Signals may be conveniently divided into two kinds: 'caution' and 'stop', though each is again sub-divided. As it is difficult for a heavy, speeding train to pull up under half a mile or so, the signals are arranged so that the driver first comes to the 'caution' or distant signal. If that distant signal shows clear, he knows that the next signal, which will be nearly a mile further on, will also be clear,





(*Left*) Long-range multi-unit colour-light signal which has replaced an ordinary semaphore signal post. Lights—red, yellow or green—are shown day and night, and are operated by the signalman by either electric or manual levers, or thumb switches. Above the signals on the left is a route indicator, which can show, for instance, platform numbers for which the points are set. (*Above*) 207-lever all-electric power interlocking frame at Waverley East, Edinburgh (L.N.E.R.). The short hand-levers operate the points and signals by means of electric power, and can be adapted to work either the ordinary semaphore type of signal, or the colour-light type. (*Courtesy of General Electric Co., Ltd.*)

and he can keep up his top speed. If the distant signal is at caution, he may pass it, but must be prepared to stop at the next signal. A notch in the signal rodding prevents the distant being placed to clear until the next signal has also been placed to clear, making it impossible for a train driver being suddenly accosted with a 'stop' signal except in emergency.

The use of this notch arrangement is known as 'interlocking', and is used extensively, especially at junctions. Before the signal reading to a particular line can be taken off, the points must first be set up for that route. At a large junction with many crossings and routes, the interlocking becomes more complex. If a train is to cross through several sets of points, they all have to be in position and tightly fitting before the signal reading for that route can be released.

The distance between the 'distant' signal and the next signal varies with the maximum speeds and weights of trains, and the gradients of the line. A graded chart has been scientifically compiled from which, on given conditions, this distance—commonly called the braking distance—can be ascertained. Often it is in the region of three-quarters of a mile.

All signalling apparatus is constructed so that should there be any type of failure, a danger indication is given. If, for instance, a signal wire breaks, the signal arm is so weighted or balanced that it falls to or remains in the danger position. Should the batteries feeding the telegraph instruments fail, even though the line may be clear, the instrument shows 'line blocked'. The mechanical balance of the dial is such that when the electric contacts are not energised, the needle falls to the 'line blocked' position.

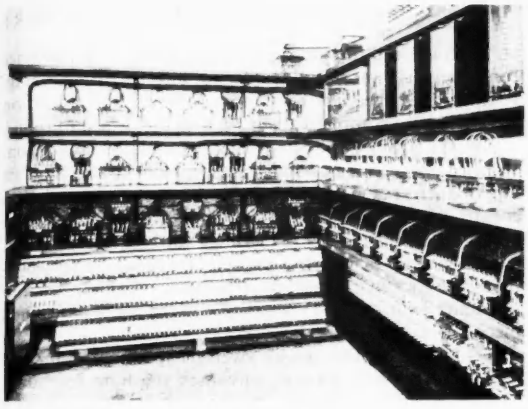
The same principle is applied throughout the whole signalling system. An interesting example is found in use in certain tunnels. A wire runs alongside each wall, and should anything untoward happen to a train in or near the tunnel, the guard has to break the wire, which in turn sounds an alarm in the signal-box, and interlocks the signalling apparatus, preventing a second train from being erroneously allowed on that same section. But should the wire break due to a fault somewhere, the same indications would be given, and the same protective measures taken.

In railway signalling, electrical science is being applied on an extensive and growing scale. At many large terminal and junction stations, all-power signal-boxes are in use, with almost every conceivable device for safety and speed. Instead of long, cumbersome levers connected by wire and rodding to points and signals, small hand levers and thumb switches are in use, the moving of which starts up electric motors, or releases electro-pneumatic pressure, placing points and signals in the desired position.

The tendency also is to incorporate the work of several mechanically operated signal-boxes into one electrical box. At Waterloo, for instance, is one power box which has taken the place of six manually operated boxes, making for speedier movement of trains in and out of the station's 21 platforms. The Westinghouse Brake and Signal Company who made this and many other similar installations, have also incorporated wide use of their electrical relay interlocking.

An impression of what can be done with a power-operated signal-box can be gathered from those which have been fitted with small thumb switches, the turning of which operates points and signals. To set up a route, the signalman needs to move only one switch; in one instance this simple action moves fourteen pairs of points, and finally the signal reading for that direction.

From the turning of the switch to the route being perfectly set up takes just six seconds. The thumb switches are placed on the diagram that shows all the lines under control, or at the foot of it. On the diagram are usually tiny electric bulbs, and when a particular route has been



(*Above*) Corner of a typical Relay Room showing D.C. and A.C. relays. This equipment is usually housed adjacent to groups of signals, or beneath signal-boxes, or in specially built cabins. Note the fuse and terminal racks. All circuits in railway signalling are separately terminated, fused and identified with the signals, points, 'track circuits', etc., which they serve. (*Right*) On the extreme left can be seen a pair of points that are in the facing direction. In the metal box is a point machine which, on working a thumb switch or signal-box lever, operates the points. Before the signal reading through the points can be taken off, they must be securely locked in position. (*Courtesy of General Electric Co., Ltd.*)

set up, the relay interlocking proving that all the points are fitting correctly, the little lamps for the route in question light up.

At Thirsk, on the L.N.E.R., the power-operated installation made by the Siemens and General Electric Company covers some 28 miles of busy main line. It has proved so successful and has so completely satisfied the railway engineers that this type of signalling has come to stay.

Throughout the railway system, interlocking is becoming increasingly more electrical rather than mechanical. At numerous manually operated boxes, the points themselves, after the point levers have been pulled, have to fit tightly and firmly in order to make an electrical contact before the signal reading through those points can be placed to clear. In many instances this electric interlocking is also connected to the telegraph instruments so that the signals for that line remain locked to danger until the appropriate telegraph messages have been sent and received.

Much of the line adjacent to signal-boxes, especially at busy places, is electrified with a low-voltage current fed from batteries. This system is known among railway engineers as 'track circuiting'. When a train passes over the section, an indication is given in the signal-box, sometimes by an indicator that shows 'train on the line', sometimes by lighting up electric bulbs on the signal-box diagram. Signals in the rear of the train, as well as telegraph instruments, are frequently electrically interlocked by the 'track circuiting', reducing considerably the chance of human error. At some places, a train passing over 'track circuiting' also sounds a buzzer in the signal-box.

Colour-light signals are gradually superseding the semaphore type, and are undoubtedly the signals of the future. In appearance they are not unlike road traffic signals, but the wiring is much more complicated to fit in with railway requirements. One important feature of this type of signal is that it can be seen remarkably well in fog. Though the lamp itself is usually only 12 or 24 watt, the ellipsoidal reflector and the powerful lens are so constructed as to concentrate the light in a strong beam about the level of the driver's eye as his train approaches. On a clear night, some of these signals can easily be seen for two miles. One kind, made by the Siemens and General Electric Signal Company, can be seen, even in bright sunlight, for distances up to 6,000 feet, although it is only a 12 watt, low-voltage instrument.

With ordinary oil-lit semaphore signals, the signalman has to allow, during fog or falling snow, an extra section between trains until fog signalmen equipped with oil hand-lamps or flags, and explosive detonators, have taken up their position at the signals, a procedure that entails much delay.

Colour-light signalling has been in operation for many years at certain important railway centres like Leeds, Manchester, York, Edinburgh and Glasgow, as well as in numerous other districts and at nearly all the London stations.

In time, the delays and difficulties due to fog will be reduced almost to a negligible amount. But it is not practicable for any quick change on a nation-wide scale. Apart from the terrific initial cost, waste of present apparatus, and the dislocation involved, there is the question of safety. Experience has proved that any change in signalling method and policy should be gradual, to give railway operating staffs the opportunity of becoming familiar with the intricacies of new methods and to enable the railway authorities to evolve the best signalling systems; this evolution involves experiment and also close contact with methods of other countries. The soundness of this policy can be judged by the high standard of safety on the British railways today. Witness that in 1943 the official figures revealed the liability of loss of life to passengers was one in 440 millions carried, despite black-out and other wartime restrictions.

A unique signalling system is that on London's Underground. On the Underground the normal position of signals is 'clear', instead of 'danger' as on the main lines. Nearly all the signals are of the colour-light type. Fixed on the line near the signal is a metal catch, and as a tube train passes over it a gadget on the train depresses the catch, switching the green signal light to red, or to yellow if a 'caution' signal. On passing the next green signal, it also turns that one to red. When it reaches, say, the third signal, the train not only actuates that signal and changes it but causes the first signal to show green, allowing another train to follow up closely behind. The signals are so arranged and placed that while the first train is at a station, the second train is allowed to leave the previous station. And by the time the first train has left its station, the second can follow it up into the platform without delay.

Allowing for curvature of the line, and distances between stations, the wiring is so planned that, with the second train following on the closest possible margin, the signals as they come to the driver's view have turned to green. Loss of time by slowing down and stopping intermedially is thus reduced to a minimum. So thorough and regular is the testing of the wiring and installations that even slight irregularities rarely occur, making the Underground one of the safest traffic routes in London.

Signal-boxes are placed at certain locations, mainly where junctions exist. They usually cover many stations and long sections of line, the signalmen in some cases never seeing the trains they signal. The illuminated diagrams tell the signalman all he needs to know about the movement of the trains.

To allow for an Underground driver inadvertently passing a signal at danger, a trip cock is fixed on the line-side working in conjunction with the signal. With the signal at danger, the trip cock would engage a stop on the moving electric train, quickly bringing it to a standstill. Even so, drivers are not encouraged to rely on this safety arrangement; it is an emergency device only; and when it is put to use, detailed reports have to be made to London Transport headquarters as to how and why the irregularity occurred.

Unlike steam locomotive drivers, the tube driver is usually alone. Should he become incapacitated and lose control of his train, the driving lever becomes disengaged by a spring arrangement immediately he relaxes his hold, and this not only switches off the motors, but applies the brake—sufficiently gradually to avoid undue shock to passengers. 'Dead man's handle' is the colloquial term used in railway circles for this device.

In quite another direction, experiments have been made on a large scale with the Hudd system of Automatic Train Control, scores of miles of line being worked by it and proving satisfactory. The idea, simply, is to give an audible warning to a driver as his train approaches a signal. If the signal is 'off', a horn in the driver's cab gives only a short blast. If the signal is 'on', the horn continues its blast, and the brake for the whole of the train is applied, unless the driver acknowledges the sound of the horn by depressing a special hand plunger.

The outstanding feature of this system, in which it differs from that used on the protected Underground Railway, is that there is no mechanical contact between the apparatus on the track and that on the locomotive, and thus weather conditions like snow and ice do not affect its functioning. Neither does speed present any problems, the operation having proved completely reliable with the fastest of trains. Automatic Train Control depends upon electric induction. Situated about two hundred yards in front of the signal is a permanent magnet, which is fixed between the rails and constructed of well-tested materials to withstand vibration and the elements. Twenty or thirty yards further on is an electro-magnet, similarly situated. Underneath the locomotive is a receiving unit, the iron plate of which picks up an induced current and transmits it to the train-controlling mechanism.

As the locomotive travels over the permanent magnet (the first), the induced current causes the horn to sound; and when the locomotive passes over the electro-magnet a little further on, if the signal it relates to is at 'clear', the electro-magnet is energised, and reverses the armature mechanism on the locomotive, silencing the horn. But should the signal be 'on', the electro-magnet on the ground would not be energised, and therefore not reverse the armature on the locomotive apparatus. In that case the horn would continue sounding, and after a few seconds, air passing through a timing reservoir would lift a valve, admitting the air to the vacuum pipe and applying the brake. The valves are so constructed that an even brake application is made, stopping the train within ordinary braking limits and without shock to passengers.

Should the driver, however, desire to silence the horn and to cancel the brake application (meaning that he is aware of the proximity of the signal), he would press a plunger near his driving controls, resetting the armature of the impulse receiver to normal.

Though there are some variations, these are the principles of Automatic Train Control, the advantage of which can easily be visualised, especially in misty and foggy weather when the sighting of signals from a moving train invariably causes delay. So far it has been mostly fixed at distant signals, for the distant or warning signal is extremely important in signalling layout, being the driver's first intimation of the position of 'home' signals protecting junctions, stations, marshalling yards and the like.

Whether the railway track is for steam locomotives, or for electric trains running on current supplied through the rails or overhead power wires, Automatic Train Control has, without any modification, met all expectations.

With the rapid growth of the radio telephone during wartime, particularly in connexion with ships and aeroplanes, it has been suggested both here and in America that some form of radio control could be used for railway signalling. But there seems to be little evidence, and little likelihood, of radio displacing the present telegraphic, electrical and mechanical signalling methods—except as a means of communication between headquarters, control offices and stations. In certain countries, however, where goods trains are of great length, radio communication is in use between driver and guard.

In the field of signalling, the British railways have vast plans for future development; and judging by the results of the extensive experimental sections now in use, they will, as times become more normal, build up a service far superior to anything that has been seen before.

The Bookshelf

Histoire de la science. By Pierre Rousseau. (Paris, Fayard, 21st Edn., 1945; pp. 823. 148 francs.)

PIERRE ROUSSEAU, who is a well-known scientific writer, considers that the history of science should not be merely a chronological record of scientific progress or an account of the lives of scientists. Science is to him as much a social phenomenon as art, literature or religion. It does not grow isolated from civilisation but takes root in the social, political, economic and ideological content of each particular period. The triumph of the Cartesian method in the seventeenth century could, according to the author, only have been possible in the atmosphere of order and harmony which marked the century of Louis XIV; he sees the tormented work of an Ampère as the logical product of the Romantic Age.

It is from this angle of general history that the author has traced the history of science from the dawn of civilisation to the eve of the atomic bomb. This treatment, while giving an attractive and logical background to the history of science, has obvious drawbacks. The link connecting scientific evolution with the contemporary content of civilisation is not always very strong. Moreover the chronological sequence has sometimes to be reversed; so, for example, the author makes Poincaré precede Darwin. But in spite of these drawbacks the ensemble is more readable and attractive than a mere chronological account of scientific development would have been. As a reference book, it is valuable. E. M. FRIEDWALD

Atomic Energy in War and Peace. By G. G. Hawley and S. W. Leifson. (Reinhold, New York, 1945; 15*s*.)

No doubt, one day, there will be several good textbooks on atomic energy. Meanwhile the limited number of facts which have been published, together with a welter of more or less inspired guesses appear and reappear in various guises. This is all to the good; one of the objects of releasing the Smyth Report was in order that scientists should be able to help their fellow citizens in reaching wise decisions on the use of the new power. This book sets out with such intentions, and one could legitimately hope for much from a collaboration between the technical editor of a large American publishing house and a professor of physics. Unfortunately, however, the flippancy which these authors find necessary in explaining the technical aspects to the lay reader makes any serious discussion of the future of atomic energy in war and peace very nearly impossible. The result is that, belying its title, only 20 of the book's 120 pages are devoted to a superficial discussion of these questions.

The treatment of the technical section is on the whole logical and sound, leading the reader unhesitatingly through the maze of concepts which underly the ultimate achievement of the release of atomic energy and concluding with a summary of the Smyth Report. A few careless statements and slips will catch the eye of the informed reader but these are not serious. What is to be very much regretted is the manner of presentation of this information. For example, 'horrendous' numbers of molecules are manipulated by 'super-duper' physicists, while explosions are described as 'combustion processes which have a couple of extra wrinkles', and so on. with exclamation marks scattered freely through the pages. This method of popularisation, while perhaps extending the possible readership, defeats its own ends because it is the extravagant and paradoxical phrases which stick in the reader's mind rather than the logical development of the subject which is being explained.

The shirking of the real social issues is a charge which must be levelled at others who have set out to discuss them besides Messrs. Hawley and Leifson. The fact is that the technical achievements are so fascinating and embrace so many different branches of science that most writers or lecturers, however excellent their intentions, find their time or space consumed only too rapidly by the technicalities and thus easily excuse themselves from tackling the larger problems. Most popular publications which claim to deal with both aspects of atomic energy deal with one of them inadequately and readers might be well advised to look out for those with a more limited scope.

C.G.A.H.

Plastics Scientific and Technological. By H. Ronald Fleck. (Temple Press, London, 1946; pp. 361, 30*s*. 2nd edn.)

THE author has tried in fifteen chapters to give as much information as possible on chemical, physical and technological aspects of plastics. In view of the fact that both editions were written during the war, one can appreciate the difficulties that he may have met in his attempt to obtain the latest 'inside knowledge'. In certain instances where wartime secrecy has made it impossible for him to be up to date one feels a fellow sympathy.

Some of the chapters are well filled with technical detail and chemical formulations; others are very brief, and the lack of balance that results ought to be rectified when the next edition is prepared.

The author has also attempted to give the reader a brief survey of the economic aspects of the plastics industry, mainly from the point of view of the supply of raw materials. Here one is surprised to find that coke oven gas as a source of ethylene is omitted from the potential sources of raw materials that are listed. Another omission occurs in the pages on carbon black (pp. 139-140) where no mention is made of the production of this reinforcing agent, vital for the rubber industry, from coke oven gas enriched with coal-tar derivatives; this method is the most suitable one for Great Britain, which at present has to import nearly 40,000 tons of carbon black a year from the U.S.A. Germany produced some 70,000 tons a year by this method, which was successfully used also in Czechoslovakia.

Fig. 1, showing the geographical distribution of raw materials for plastics, could be improved; according to this illustration there is no coal in the whole of Asia, Africa, South America, Australia, or Central or South Eastern Europe!

Good books on plastics are few. (One of the best, *Plastics* by Yarsley and Couzens, is an elementary and 'popular' book, published in the Pelican series.) *Plastics Scientific and Technological* goes some way towards helping to fill the big gap which exists between the 'popular' books and the abstruse textbooks on plastics. G.L.

Actions of Radiations on Living Cells. By D. E. Lea. (Cambridge University Press, 1946; pp. 402, 21*s*.)

THE atom bomb is the most spectacular and impressive achievement of modern nuclear physics. No wonder that nowadays even the layman can flatter himself that he is aware of the importance of radioactivity and it is natural that he wishes to know more about its repercussions on the living organism, including himself. Thus the publication of this book is very timely. It is not a mere compendium or encyclopaedic summary of experimental facts, but an attempt to interpret the effects of radiation by various rays on an exact physical basis. The task is a very difficult one because the responses of living organisms, owing to the variability which is their fundamental property, cannot be measured with the exactitude of physics. Any quantitative analysis of radiation effects, therefore, is bound to be of great complexity. The author, however, has tackled this problem in a competent manner. He relies on assumptions and simplifications in his interpretations; by imposing this limitation he was able to arrive at conclusions which are valuable and useful as the basis of various working hypotheses, not only to interpret but also to predict the effects of radiation. The book contains all the pertinent data concerning not only the cell but also the viruses and bacteria. The various methods which may be used to determine the size and internal structure of viruses, many of them developed by the author himself, are presented. Amongst the effects which radiation induces in cells only those which can be detected by cytological or genetical methods are discussed. Those radiation-induced effects which are concerned with the enzyme activity of highly specialised cells and which may have a great importance in medicine are only touched on very briefly; the reason is our lack of knowledge in this field. The value of the book lies not only in the fact that it summarises our recent knowledge on the radiation effects in cells, but also in the fact that it draws attention to those gaps which must be filled by further research. Dr. Lea's synthesis will no doubt stimulate biologists, chemists and physicists to a greater integration of their sciences. P. C. KOLLER.

Far and Near

Chemical Research Exhibition

THE exhibition arranged by Imperial Chemical Industries at the Tea Centre, Lower Regent Street, London, S.W.1., closes on June 28. The exhibits illustrate a number of themes interesting to both scientists and the general public; these include 'The Chemist versus Disease' (sulpha drugs, penicillin and Paludrine), 'The Chemist and Your Food' (synthetic fertilisers, and the selective weedkiller called Methoxone), 'Chemical Warfare against Insects' (benzene hexachloride or gammexane) and 'The Chemist and Plastics' (Perspex and polythene). The final section is devoted to Ardil, the wool-like fibre made from monkey-nut protein.

The exhibition is open from 10.30 a.m. to 8 p.m. (Sunday 2 till 7 p.m.). The admission charge is 1*s.* and all proceeds go to the Empire Fund for Cancer Research.

Atomic Scientists Association

AN association has been formed of scientists normally resident in Great Britain who have been connected with atomic energy projects in this country, Canada or the United States. It is called the Atomic Scientists Association.

The aims of this new organisation are as follows:

1. To provide a forum for the discussion among scientists of the scientific, social and international problems arising out of the release of atomic energy.
2. To keep these problems before the public and to press for a positive political programme for their solution.
3. To disseminate and explain published material on atomic energy and particularly on its implications both to other scientists and to the general public. Also to provide an agency for the countering of misleading statements.
4. To make and maintain contact with scientific and other bodies on this country with whom some aim is held in common.
5. To form and maintain a library of books, papers and other publications relating to these objects.

A provisional committee has been set up consisting of the following members: Professor H. S. W. Massey (chairman); Dr. G. O. Jones, Professor R. E. Peierls, Dr. J. Rotblat, Dr. S. Devons; Dr. W. J. Arrol and Dr. E. H. S. Burhop are the joint hon. secretaries.

Any communications should be addressed to: The Secretary, Atomic Scientists Association, University College, Gower Street, London, W.C.1.

Scientific Man-power Report

THE Scientific Man-power Report of the Barlow Committee appointed by the Lord President of the Council was published by Stationery Office last month (Cmd. 6824, price 6*d.*) The committee assesses "the absolute maximum potential capital of qualified scientists in 1946" at 60,000 and estimates the minimum demand for scientific workers in this country and in the colonial service in 1950 at 70,000. Taking into account information received from the University Grants Committee, expansion in the science departments of the universities could increase the annual output of science graduates from the pre-war figure of 2500 up to 3500 by 1955.

The committee suggests that Britain may be seriously short of scientists in 1950; it estimates a deficit at 10-15 thousand.

The immediate aim, recommends the committee, should be to double present output, to give about 5000 science graduates a year at the earliest possible moment. The committee holds that there is an ample reserve of intelligence in the country to allow this aim to be reached with a simultaneous raising of standards. A system of priorities to secure the best use of our limited supply of scientists is suggested; the order given is: (1) Teaching and fundamental science, (2) Civil Science, both Government and Industrial, (3) Defence Science. The first thing to be done is to ensure a sufficient number of qualified teachers.

Big DSIR Grants for Nuclear Research

THE largest grants with which the Department of Scientific and Industrial Research are dealing at present are those to Professor P. I. Dee at Glasgow University. This statement was made by the DSIR's secretary, Sir Edward Appleton, last month. He said that the two grants were of the order of £140,000 and £50,000 respectively. Professor Oliphant's grant, he added, would finance an attempt to obtain atomic particles with speeds corresponding to energies of 100 million volts.

S.M.A. Widens Membership

MEMBERSHIP of the Science Masters' Association will be open, as from October 1, to all science masters, holding a university degree, in approved secondary schools. This change in the association's constitution was made at the annual meeting held in the City of London School on April 15-18. At the same time an Associate membership was created; Associate Members must be masters teaching science in approved secondary schools, but they need not possess a university degree. The effect of this change is to extend membership to masters in the new types of secondary school on equal terms with existing members, and in addition to provide for the large number of science masters in these schools whose training has not included the taking of a dregee.

At the meeting there was a full programme of lectures, visits and exhibitions. Publishers and scientific apparatus manufacturers produced a show of pre-war comprehensiveness, and there was an encouraging display of projection apparatus, including a number of well designed film side projectors. The members' exhibition was noteworthy not only for the ingenuity and appositeness which we have come to expect, but for the use made of modern developments. A striking exhibit was a small-scale Van der Graaf generator, which produced magnificent 2-inch sparks with the help of a miniature Wimshurst machine, and could also be arranged to continue to charge itself from an earth connexion. Near this was a high-tension rectifier arranged to work electrostatic experiments such as Hamilton's mill, together with some examples of the use of Perspex and polythene. These plastics have such good insulation, even in an atmosphere of high humidity, that the ordinary electrostatic experiments can be made to work every time—a welcome change from the ebonite-and-glass regime. Another high-tension rectifier, of extreme simplicity, producing 2000 volts, was fed to a simple form of Geiger counter for demonstrating radioactivity. These examples have been selected to indicate the trend mentioned above in one field, but there was a wide variety of exhibits in all branches of physics and chemistry. Biology was represented chiefly in the exhibition of graphic material, a new departure which proved its usefulness. This display included wall diagrams, lesson notes and samples of pupils' note-books.

The lectures were numerous and ranged over the whole field of science teaching and allied subjects; of particular interest was that by Professor H. S. W. Massey on nuclear energy.

Industrial and Medical Films

THE Industrial Committee of the Scientific Film Association is preparing a catalogue of industrial films, and seeks the assistance of DISCOVERY readers in making it as comprehensive as possible. A preliminary list containing 200 titles is available at 2*s.* and any information which would bring additions to that list would be greatly appreciated by the Committee. The title of the film, the source from which it may be hired or borrowed and other relevant particulars should be sent to: Hon. Secretary, Industrial Committee, Scientific Film Association, 34 Soho Square, London, W.1.

The Association's Medical Committee is organising a scheme of voluntary co-ordination so that duplication in the production of medical films can be avoided. Copied of a memorandum outlining the scheme are available, gratis, on application to: Dr. Brian Stanford, Hon. Secretary, Medical Committee, S.F.A., at the above address.

£300,000 for Imperial College

THE Centenary Appeal Fund of the Imperial College of Science and Technology, which was launched last year, now stands at over £300,000. The largest single donation is £118,300, from Courtaulds Ltd., which is earmarked for the

chemical engineering department. The announcement that the college is establishing a chair for concrete technology has brought a generous response from the interested industries, including the Cement Makers' Federation (£20,000) and several big building contractors.

Research on the Common Cold

A COMMON COLD Research Unit is being established by the Medical Research Council and Ministry of Health, and will start work in July. It will be housed at the Harvard Hospital, near Salisbury. As a check on their laboratory studies, workers at the National Institute of Medical Research require to test on human volunteers the cold-producing activities of materials they are studying. These tests will be carried out at the Harvard Hospital. The volunteers are being drawn from men and women students at the universities.

P.E.P. Broadsheet on Social Surveys

THE latest broadsheet issued by P.E.P., the 250th to be released since April 1933, is entitled *The Social Use of Sample Surveys* and costs 1*s*. 10*d*. post free from P.E.P., 16 Queen Anne's Gate, S.W.1. It recommends that the Government should continue to maintain its own Survey Unit, attached to either the Central Office of Information (Wartime Social Survey, it may be noted, was under C.O.I.'s predecessor, the Ministry of Information) or to the Lord President's office. Another recommendation is that the Government should start conversations with the universities, scientific and social institutions, commercial organisations and others concerned in social survey work to secure co-ordination in this field.

New Meteorological Magazine

A NEW monthly magazine for all interested in meteorology has been published by the Royal Meteorological Society. Called *Weather*, it is intended for a wider public than the Fellows of the Society, and it will carry short articles, comments on current weather, accounts of interesting observations, book reviews and news of the activities of the Society. It should interest all who regard the infinite variety of our weather either as affording a hobby or of some professional importance.

Weather will, therefore, take the place in large part of the old *Meteorological Magazine*, which ceased publication early in the war, as a medium for the exchange of what may be called the lighter type of meteorological news.

The first number is very pleasingly produced. Contributors to the first number include the President of the Royal Meteorological Society, the Director of the Meteorological Office (on 'Meteorological Research'), Professor D. Brunt on 'Meteorological and Weather Lore', Air Commodore B. H. C. Russell (on 'What I want from the Meteorologist'), Mr. J. Paton ('Aurora Borealis') and Mr. A. J. Lander ('The British Radiosonde'). A particularly useful feature is the account of the weather over the British Isles in April 1946.

This 32-page magazine costs 1*s*. 6*d*.; it can be obtained for an annual subscription of 18*s*. from the Royal Meteorological Society, 49 Cromwell Road, London, S.W.7.

Personal Notes

BRIGADIER O. H. WANSBROUGH-JONES succeeds Sir Charles D. Ellis as scientific adviser to the Army Council. Recently he has been Deputy Director of Special Weapons and Vehicles at the War Office. A scholar and Fellow of Trinity Hall, he did research under Haber at the Kaiser Wilhelm Institut in Berlin and later became a demonstrator in Cambridge's Department of Colloid Science.

THE death occurred on May 15 of Charles Albert Watts, founder of C. A. Watts & Co. Ltd. and the Rationalist Press Association, Ltd. The R.P.A., as the Association came to be familiarly known, was a pioneer of the Book Club movement. It scored its first prominent success by issuing sixpenny reprints of the chief works of Spencer, Darwin, T. H. Huxley, Tyndall, and others, at a time when this type of production was confined to fiction of established popularity. Mr. Watts lived to enjoy his full reward in the knowledge that his work as a publisher has served to bring the latest thought on the fundamental problems of philosophy, religion and science within reach of all. He was born in 1858.

Science and the B.B.C.

A conference on 'The Broadcasting of Science', organised by the Cambridge branch of the Association of Scientific Workers, was held on May 18–19. Among the speakers were members of the B.B.C. staff who are responsible for several of its more important science programmes.

Commander Ian Cox, who is responsible for 'Science Survey', laid the basis for discussion by summarising the various possible ways of broadcasting science and outlining the techniques involved in them. Discussing the functions of the producer, he pointed out that, even if he enters the B.B.C. well informed in current science, his duties are such that he cannot remain so. Therefore men whose regular work is in research or teaching must co-operate to keep the producer abreast of current developments. In recent years they have been increasingly willing to do so.

Mrs. Nesta Pain spoke on feature programmes and illustrated her remarks with recordings from actual programmes. Features, she said, should not be regarded merely as sugaring the pill, although they can be very useful for that purpose; they should attempt to put across elements of atmosphere and characterisation which are less easily conveyed in other ways.

Mrs. Mary Adams pointed out that B.B.C. producers work under the disadvantage of having little time to meet other producers or hear other programmes. Her main subject was the potentialities of television which, she pointed out, is much less suitable than sound for imaginative treatment. Nor can it compete with the film's facility for editing and shortening the time-scale. Its advantages lie in the producing of a heightened sense of immediacy. It puts greater emphasis on skilled demonstration and ability to cope with emergencies (she mentioned that during a programme on blood transfusion two camera men collapsed!). Exploration of the possibilities of television is at present held up by lack of accommodation—Alexandra Palace has only two studios—and even by lack of facilities for research in production technique. This appears to apply to broadcasting in general, if it is true, as Mrs. Adams said, that "No finance has ever been allocated to the B.B.C. for research", either in technical matters or in the technique of presentation.

Professor Bernal said that scientists themselves are largely to blame for the lack of attention to science in broadcasting and other popular media; but they are now beginning to wake up. While not attempting to become a substitute university, the B.B.C. should help the average man to get enough knowledge of science to fulfil his functions as a citizen—to vote intelligently, do his job properly in an increasingly technical world, and so on. Most people are only concerned with knowledge that will be useful to them socially or materially. Scientists should select chiefly these aspects for presentation by radio.

As a possible organisation for carrying out planned science broadcasting he suggested a Science Advisory Committee, consisting of scientists working outside the B.B.C., who would work out a broad policy, this committee to co-operate with a *scientifically trained* permanent staff who would translate the general policy into action. But while agitating for this, scientists should start to sketch a plan themselves, and this was a possible job for the A.Sc.W. to undertake.

Dr. M. H. Clifford, a W.E.A. lecturer, spoke on the objectives and techniques of adult education, experience in which he said suggested that it is not necessary, nor even desirable, for lecturers to be confined to their own research subjects. In adult education the lecturer is not an authority addressing his peers, but an expositor serving the needs of laymen as does the political commentator.

One might suggest that the B.B.C. should revive the practice of providing a proportion of longer talks for the more serious student. Feature programmes and short talks, while serving a definite and necessary purpose, are but the gateway to further education. Or is considered B.B.C. policy to stop short at pioneering activities? Dr. Clifford suggested that if the answer was "Yes", then the B.B.C. should co-operate more closely with bodies like the W.E.A.

In discussion the question was raised as to whether the B.B.C. has a broad policy on the sort of science to broadcast and the type of audience to cater for. Here there was some difference of opinion. Mrs. Adams asserted that the science output is "essentially unplanned", and that the Corporation "is not concerned with the social implications of what it

puts over" on science; nor is policy on these matters discussed except among the producers themselves. Commander Cox, on the other hand, maintained that science is discussed at policy-forming levels.

The second session was devoted to more specialised fields of science broadcasting—those on medicine and health and the services to the Forces and schools. Mrs. Iza Benzies made it clear that any successes in the first of these have been achieved in spite of discouragement and opposition from the General Medical Council.

Mr. Richard Palmer spoke on science broadcasts for schools. The fundamental objectives of these programmes he expressed in the form: "We thought it important that the citizen of tomorrow should get into the habit of thinking of science as a tool for human welfare—a tool which is socially created and socially used." He gave an account, illustrated by recordings, of the various techniques employed. Besides normal educational functions, he emphasised, broadcasts have the virtue of providing an extension of the child's experience by letting him 'eavesdrop' on pieces of scientific discovery in progress: these are reproduced imaginatively in the studio, but with respect for factual correctness.

In speaking of the science work of the Services Educational Unit, Dr. A. Clow gave some interesting figures on the questions received from the Forces for the periodical request programmes. About 50 per cent are on atomic energy; jet-propulsion and penicillin dead-heat for second place, and are followed by television and then human evolution. Questions about evolution, astronomy and geology are commoner than those about, for example, plastics.

Scientific Film Review

FOR lack of professional guidance many educational films are overloaded, include shots or sequences irrelevant to the theme, and vary the level of approach from sequence to sequence. Two recent films entitled respectively *The Microscope* and *How to File* are free of all these faults: their directors had clearly defined objectives and who have aimed at specific audiences, and in neither case has the director attempted to step beyond his clearly set limits. It is not often one sees instructional films which can give so clear an answer to the double question "To *whom* are you teaching *what*?"

The Microscope, a film for Sixth forms and first year university students, sets out to show the parts of a microscope and to teach an effective working routine, and is accompanied by a wall chart and teaching notes. The former (depicting a diagram of the instrument and giving rules of working) should be permanently on view in the laboratory for reference purposes. The latter give most useful additional information and greatly enhance the value of the film as an educational tool.

The first section of the film shows the parts of the microscope, ending with the same labelled diagram as is used in the wall chart. Quite rightly, no attempt is made to explain the optical system or the physical principles of the microscope.

This is a 'know-do', not a 'know-why', film. The subject matter of this first section might be regarded as too static to lend itself to film treatment, a fault which might have been remedied to some extent by greater use of camera angle and camera movement. However, it is a necessary introduction to the routine of using a microscope.

The second section of the film is a very competent piece of exposition, with slow sequences, clear shots and a high standard of photography. The importance of combining the correct eyepiece and objective is emphasised, but the reasons for these combinations are—again quite rightly—reserved for the teaching notes. Here the director has shown admirable restraint in not launching into explanations with animated diagrams, as he might well have been tempted to do. The dynamic quality of the medium comes into its own when the audience looks down the tube of the microscope to see the object (in this case a fly's 'nose') come into focus; indeed the whole sequence on focusing is admirable, including as it does the simple device of using a pencil when bringing the light into focus.

This is good instruction, of great value in class work where it is impossible to demonstrate the best use of a microscope to numbers of small groups. The film should prove most useful, too, for self instruction, as the clarity of exposition in both visuals and commentary make it independent of a lecturer.

How to File presents information at a different level. It sets out to show factory apprentices how to use a file, emphasising the three points—position, grip and stroke. The subject matter is not as complex as that of *The Microscope*; indeed, the film is far less ambitious, but it is nevertheless comparable in that the exposition is clear, the photography good and the pace well suited to the audience for whom the film is intended. The teaching technique, too, is different from that used in *The Microscope*. In this case, the visuals follow the instructor demonstrating to the apprentice, while the commentator gives the instructions. This is much less disturbing than a constant exchange between the instructor and learner would be. Tempo, of course, is very important, and in this well executed film it proves effective in contributing its share towards the film's teaching value.

The action takes place in a workshop where an apprentice is being shown how to use a file; the film follows his progress as he learns how to stand, how to hold the file and how to use his right arm for pressure, with the left hand for guidance. The careful photography makes all this quite clear, but the punch could perhaps have been made more effective by recapitulation of the teaching point at the end of each sequence. The film then goes on to show other types of files, such as the rat-tailed file and the half-round file, and ends very sensibly by reminding the learner that before he can carry out these specialised operations he must master the rules of simple filing—correct position, correct grip, correct stroke. As in *The Microscope*, the director of this film has borne in mind the audience for whom the film is intended, has thought out her aim and stuck to it. She has refrained from including visually interesting but irrelevant material.

The Microscope is a Realist Film Unit production, directed by Alex Strasser and Denys Parsons. *How to File* comes from the Shell Film Unit, and was directed by Kay Mander.—HELEN COPPEN.

(*This review is contributed by arrangement with the Scientific Film Association.*)

Night Sky in July

The Moon.—Full moon occurs on July 14d 09h 22m, U.T., and new moon on July 28d 11h 53m. The following conjunctions take place:

July				
1d 19h	Venus in conjunction with the moon		Venus	3° S.
3d 07h	Mars	,,	Mars	4 S.
6d 11h	Jupiter	,,	Jupiter	4 S.
31d 15h	Venus	,,	Venus	5 S.
31d 23h	Mars	,,	Mars	5 S.

The Planets.—Mercury can be seen in the western sky, setting at 21h 42m on July 1, but in the middle of the month the planet sets 40 minutes after the sun and is not favourably placed for observation after that. It attains its greatest eastern elongation on July 5 and is stationary on July 19. Venus is still conspicuous in the west after sunset, her times of setting being 22h 16m and 21h 15m at the beginning and end of the month respectively. Mars can be seen in the early part of the night, setting 2½ hours after the sun on July 1 and 1½ hours after the sun on July 31. Jupiter sets at midnight at the beginning of July and at 22h 18m at the end of the month. Saturn is favourably placed for observation and is in conjunction with the sun on July 21.

The constellation of Hercules is conspicuous and can be easily found as it lies to the left of Corona Borealis, a small constellation which cannot be mistaken because of its resemblance to a crown. Hercules is a large constellation and readers are advised to make themselves familiar with its brightest stars by means of a star map. An interesting point in connexion with this constellation is that a famous temporary star or nova made its appearance near Iota Herculis in December 1934. The nova was first seen by Mr. J. P. M. Prentice who was observing meteors at the time. It behaved rather differently from the usual novae which generally rise very quickly to a maximum brightness and then commence to fade. Nova Herculis increased steadily in brightness for about three weeks and became a star of second magnitude, after which it faded and became invisible to the naked eye.

M. DAVIDSON, D.SC., F.R.A.S.

Corrections

FIG. 14 on p. 146 of the May issue was inadvertently printed upside down. *Trichoderma* (p. 127 'Scientific Aspects of Kew') is a hyphomycete, not an actinomycete.

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